Negawatts for Buildings: Observations from 25 years

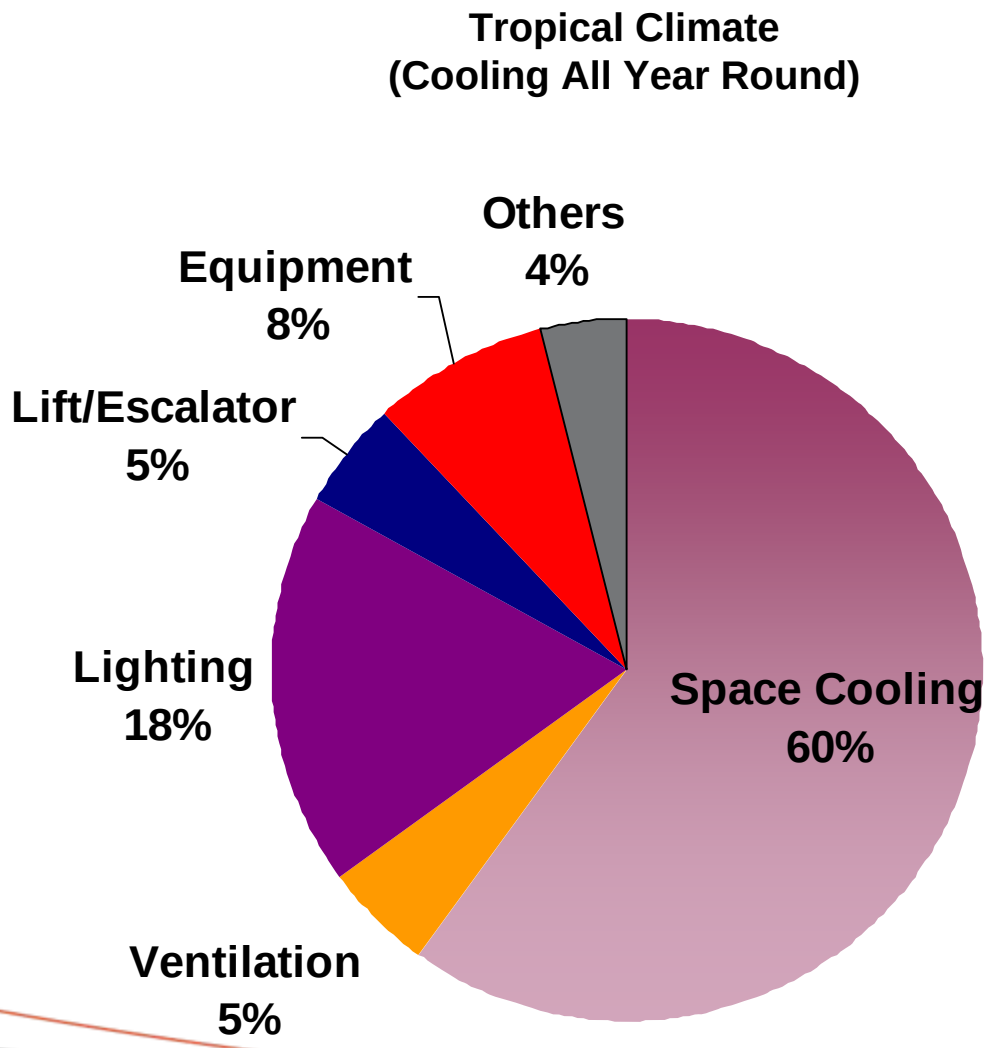
Lee Eng Lock

Trane Singapore

20 Jan 2009

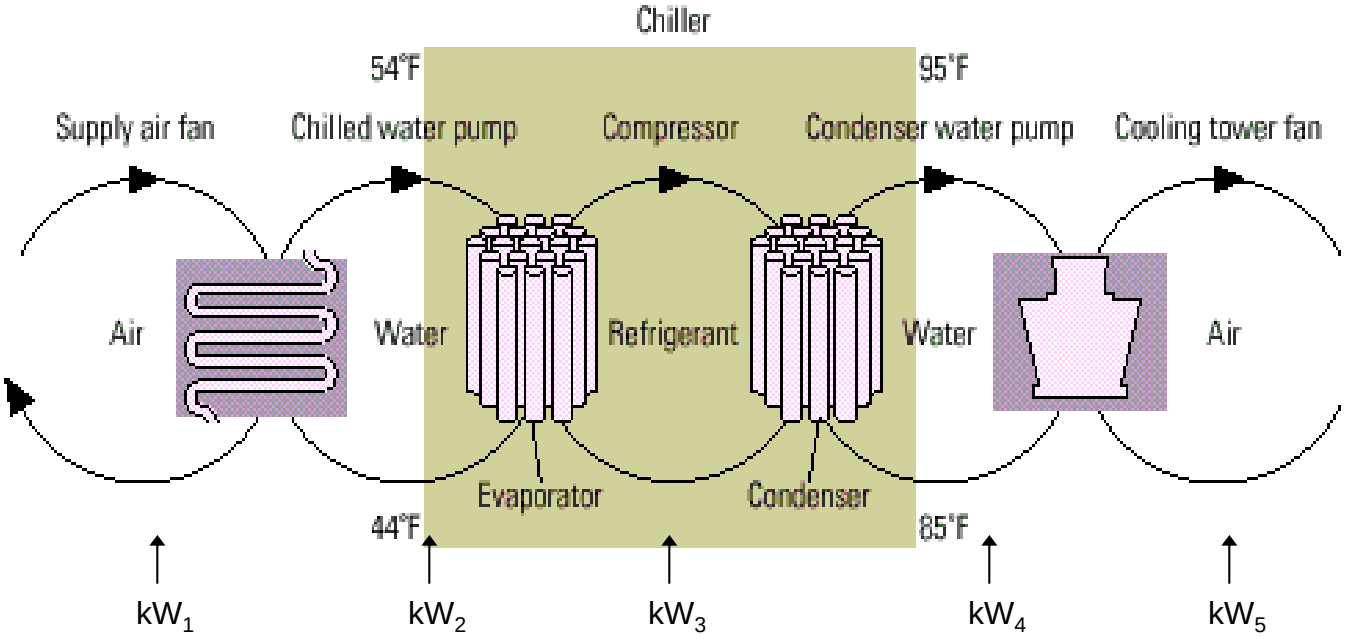
It is time for Change ……

Typical Energy usage Commercial Building



The 5 Circle Diagram

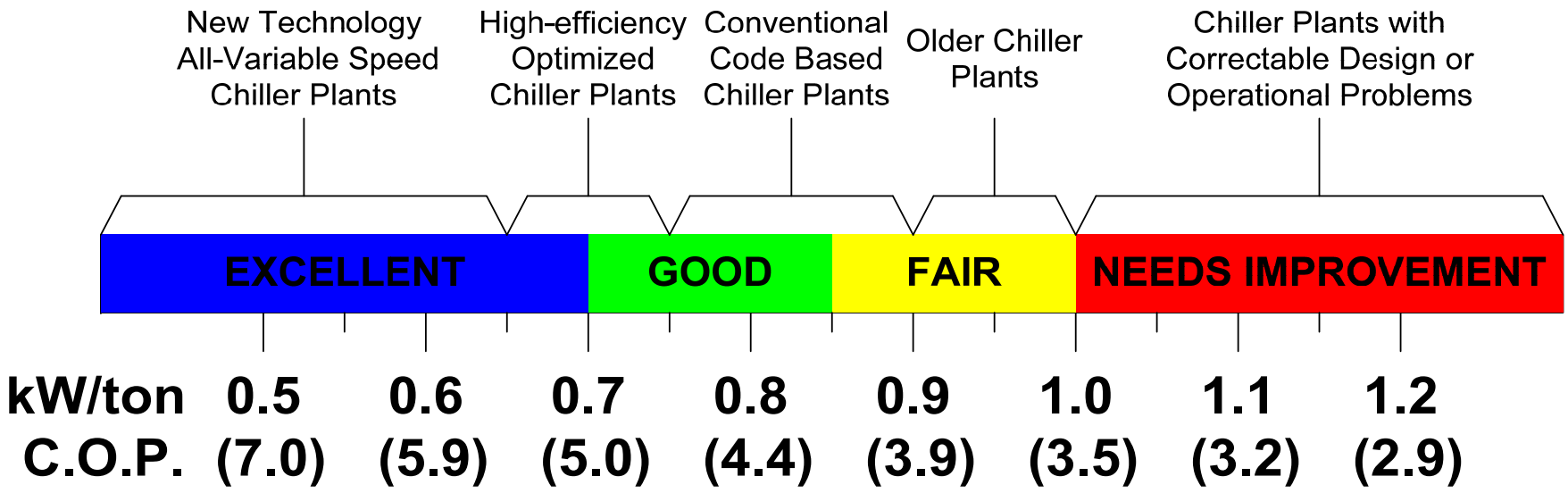
Total System HVAC Approach



Cooling System kW/Ton $= \dfrac{kW_1 + kW_2 + kW_2 + kW_4 + kW_5}{Ton}$

Parasitic Load to Chiller $= kW_1 + kW_2 \pm 10\%$

Ashrae--Chiller Plant Efficiency



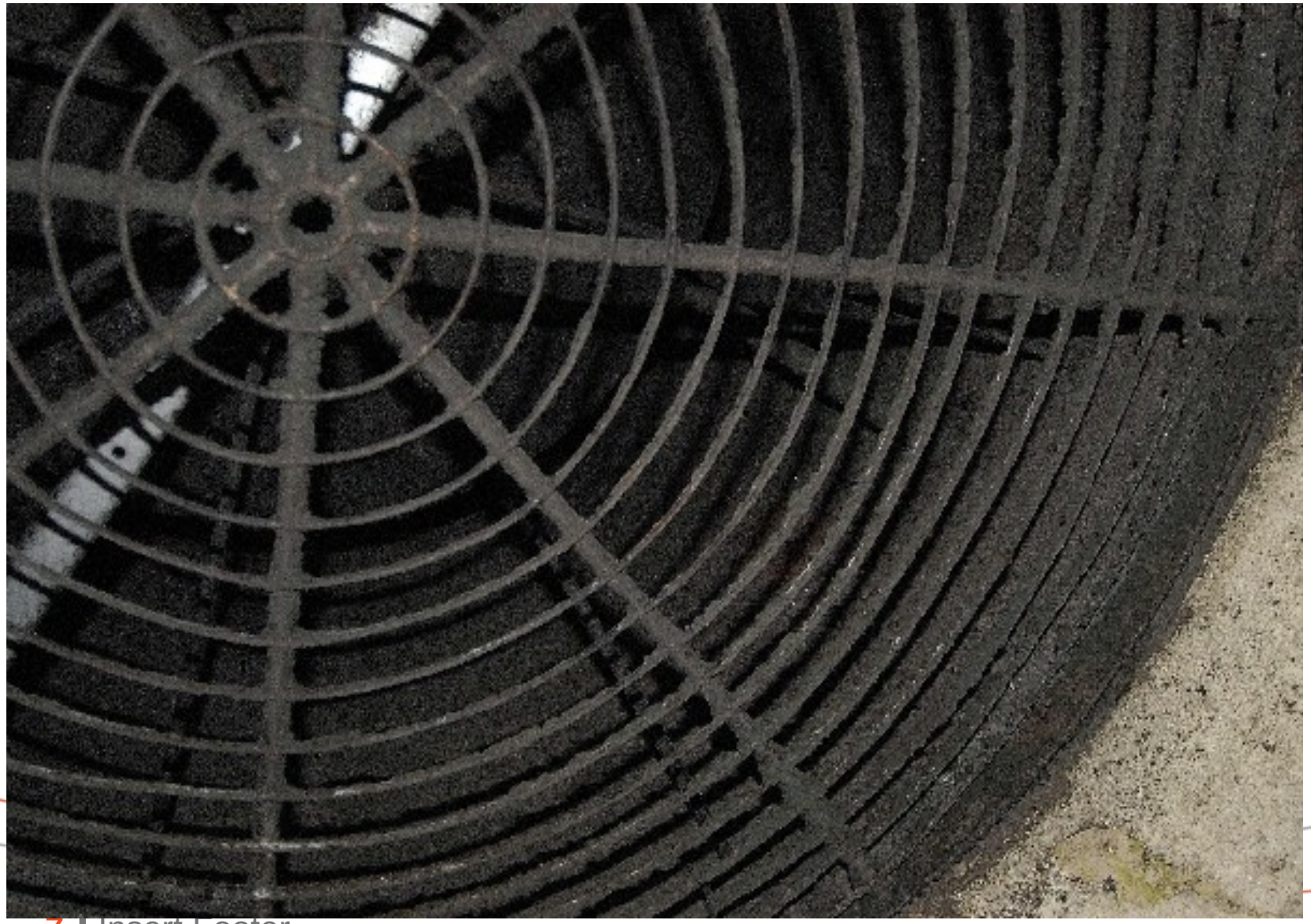
AVERAGE ANNUAL CHILLER PLANT EFFICIENCY IN KW/TON (C.O.P.)

(Input energy includes chillers, condenser pumps, tower fans and chilled water pumping)

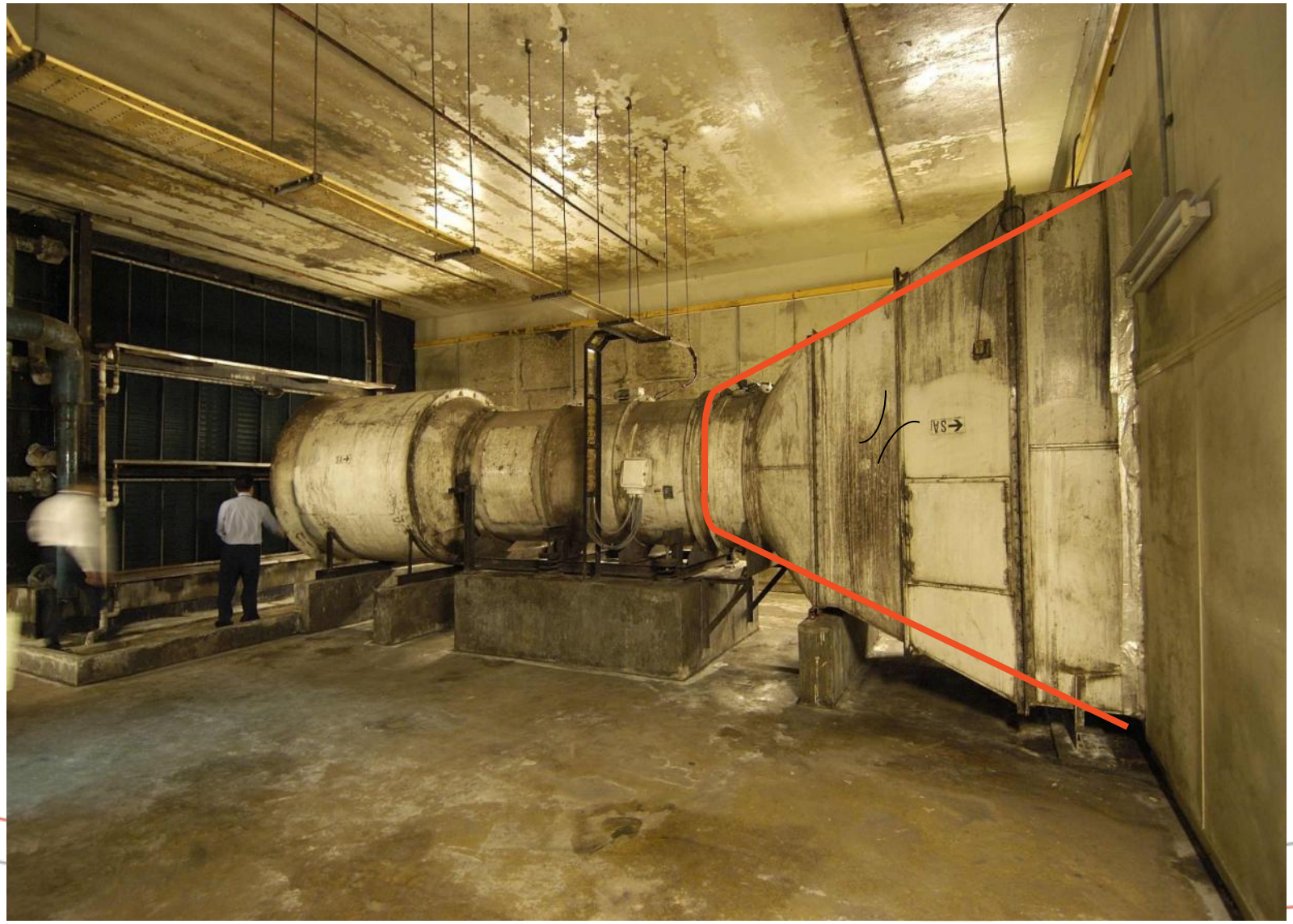
Based on electrically driven centrifugal chiller plants in comfort conditioning applications with 42F (5.6C) nominal chilled water supply temperature and open cooling towers sized for 85F (29.4C) maximum entering condenser water temperature and 20% excess capacity. Local Climate adjustment for North American climates is +/- 0.05 kW/ton

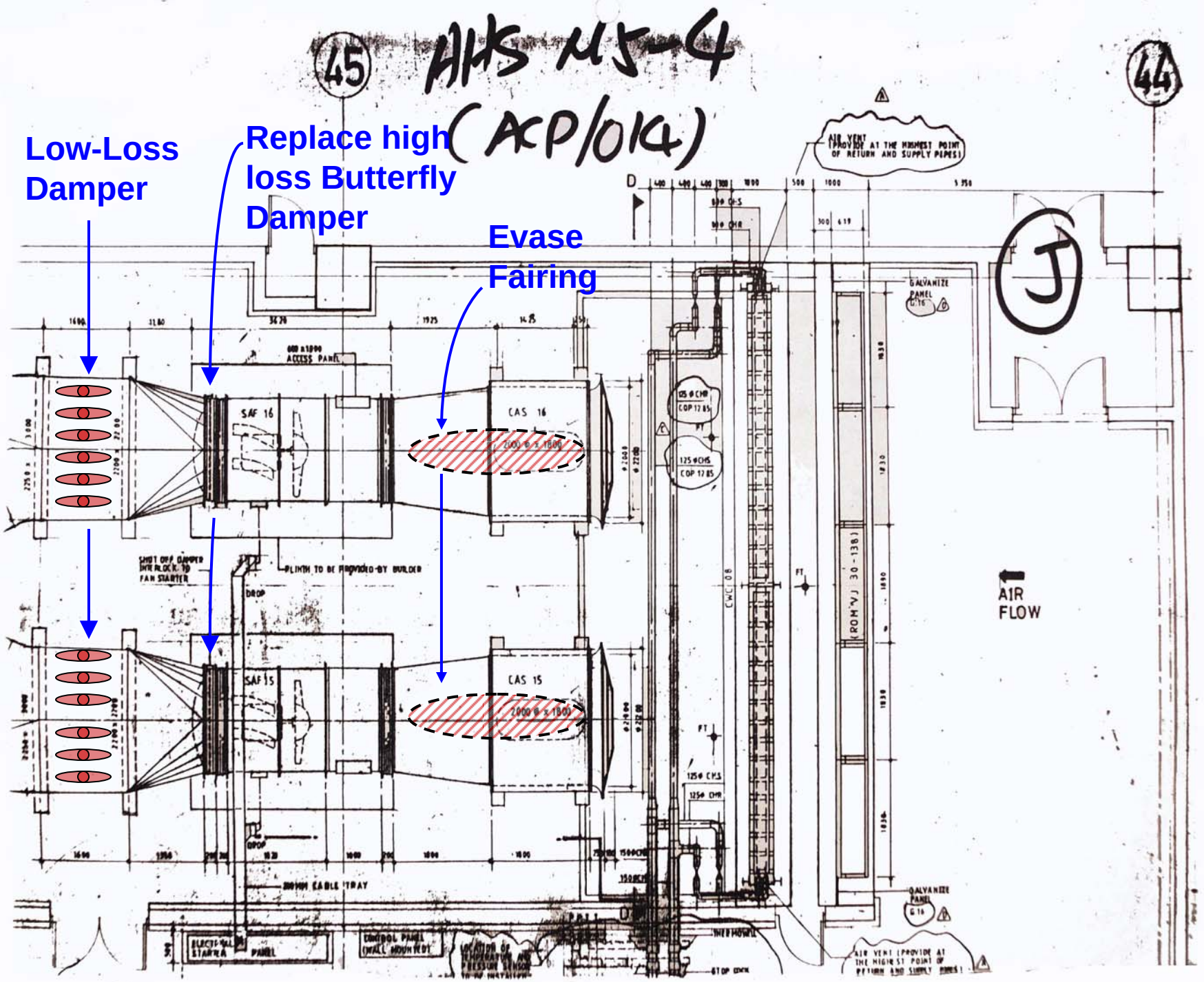
Large Built up AHU…more efficient?

Dirt on Silencer Inlet…..+ fans

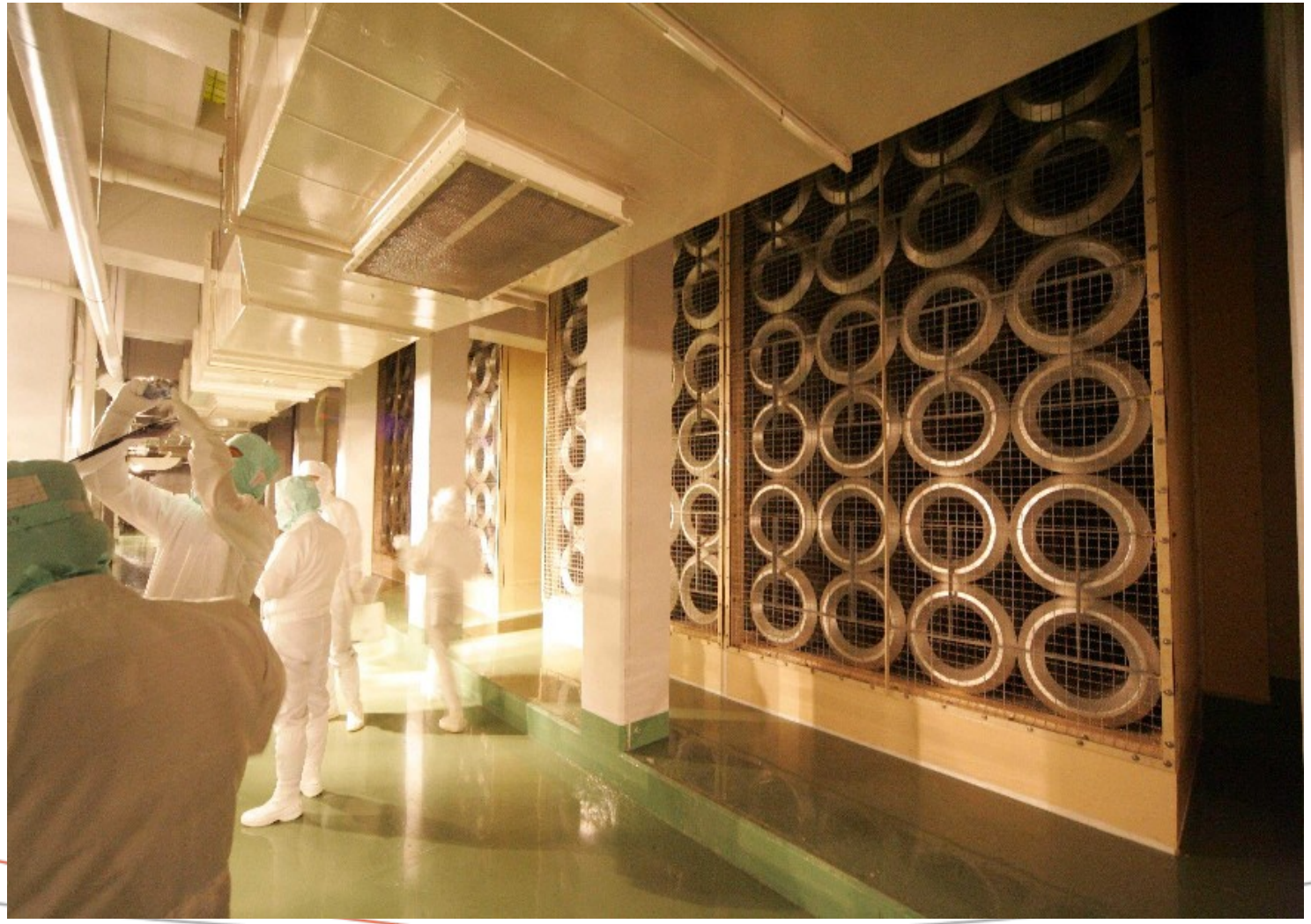


Built up AHU Axial Fan - Incorrect Flare



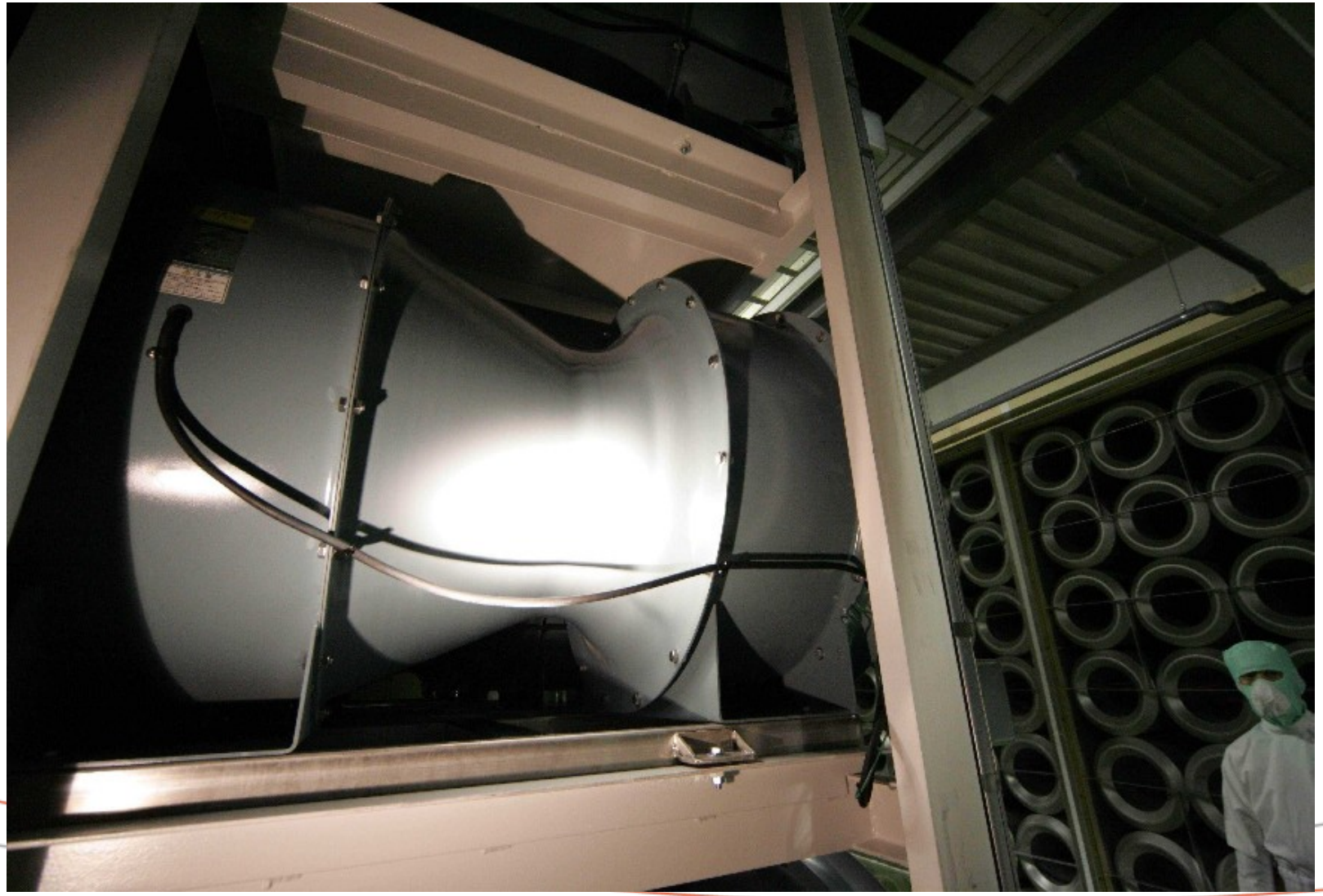

Low-Loss Damper
Replace high loss Butterfly Damper
Evase Fairing
45
AHS M5-4
(ACP/014)
44
SAF 16
CAS 16
SAF 15
CAS 15
AIR FLOW

Stainless Steel Silencer Bank

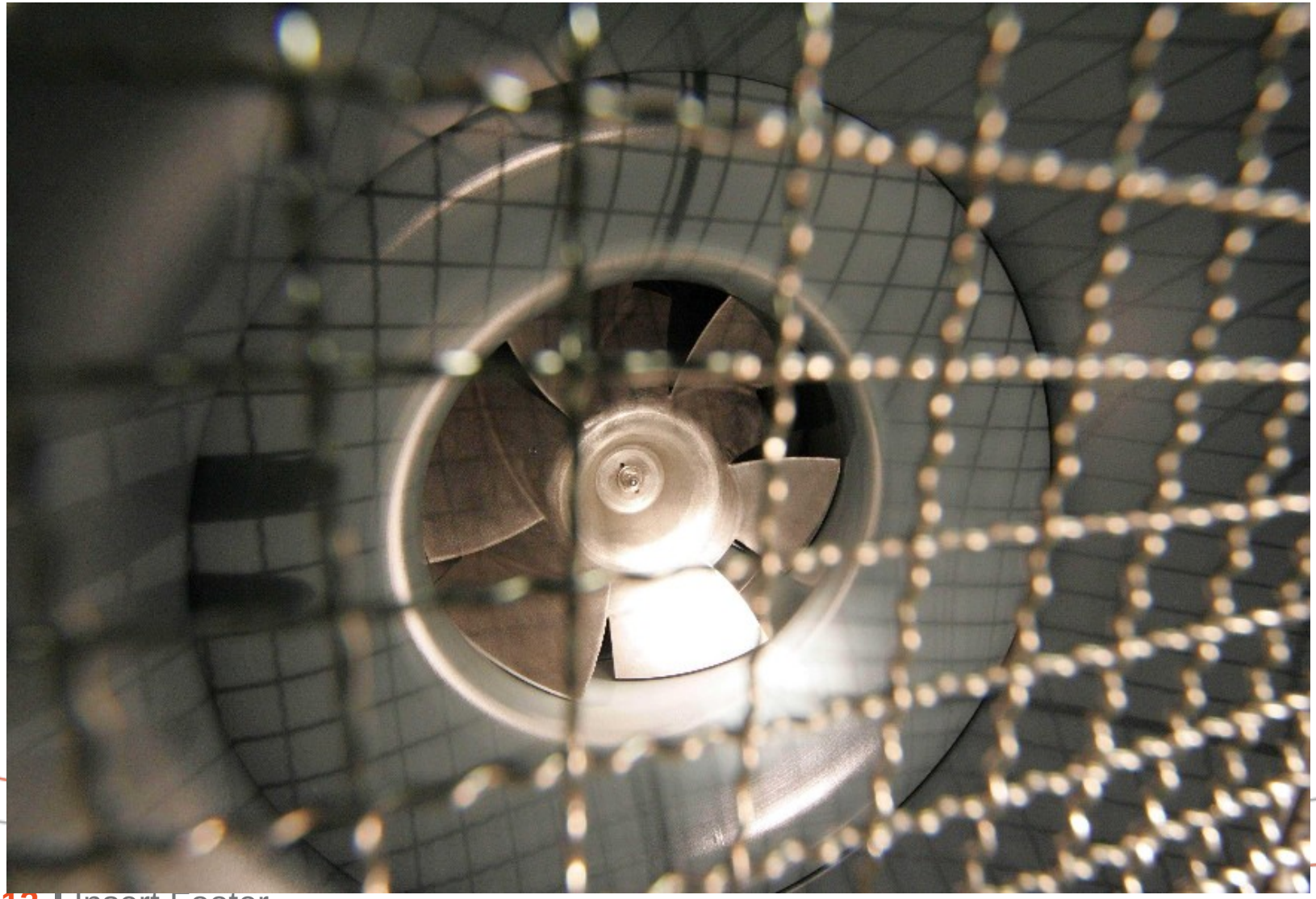


Silencers + Mixed Flow Fans

Mixed Flow Fans and Silencers



Inlet to Mixed Flow Fan

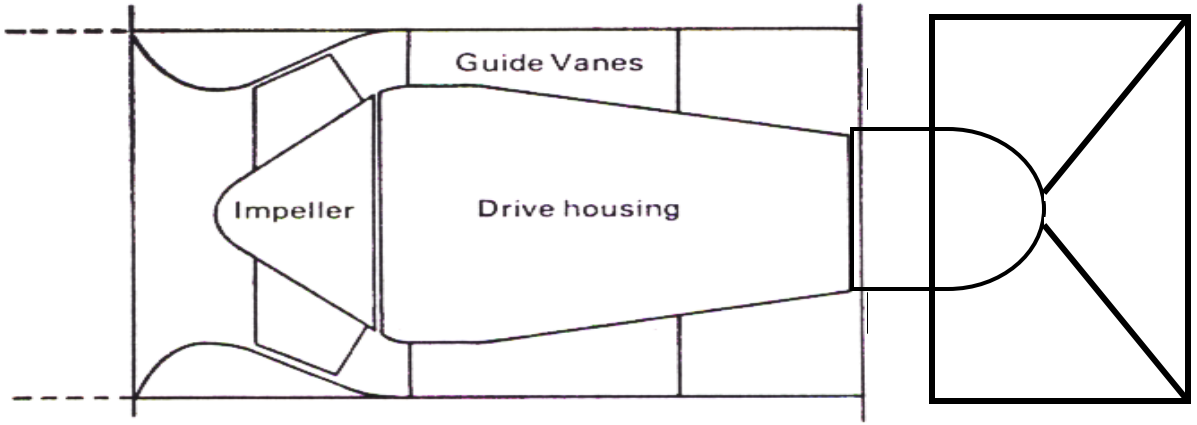


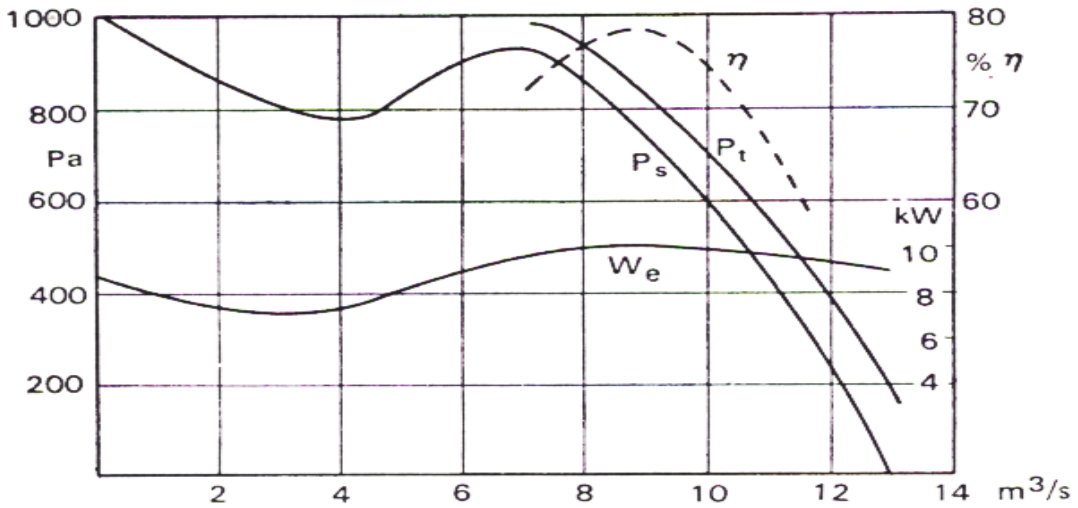
Fan Discharge + Cooling Coils

Discharge Damper Details

Mixed Flow Fan Discharge

1000mm 1100 rev/min in-line mixed flow fan





AHU ENERGY RETROFIT

CASE STUDY 1

Replacement of two Outside Air AHU
Year of completion: 2000

SUMMARY:

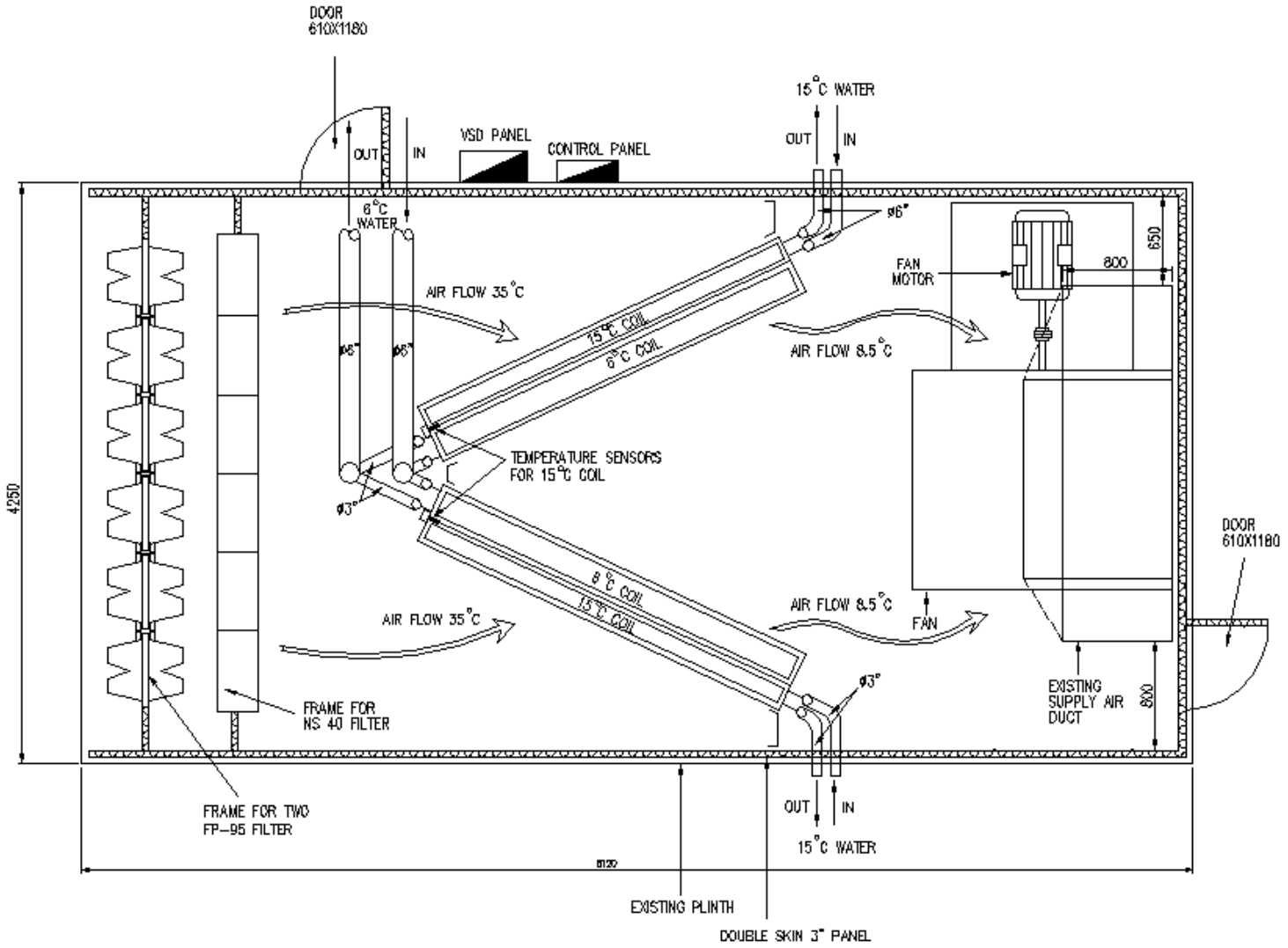
Savings of 140 kW

or 80% on

operating cost

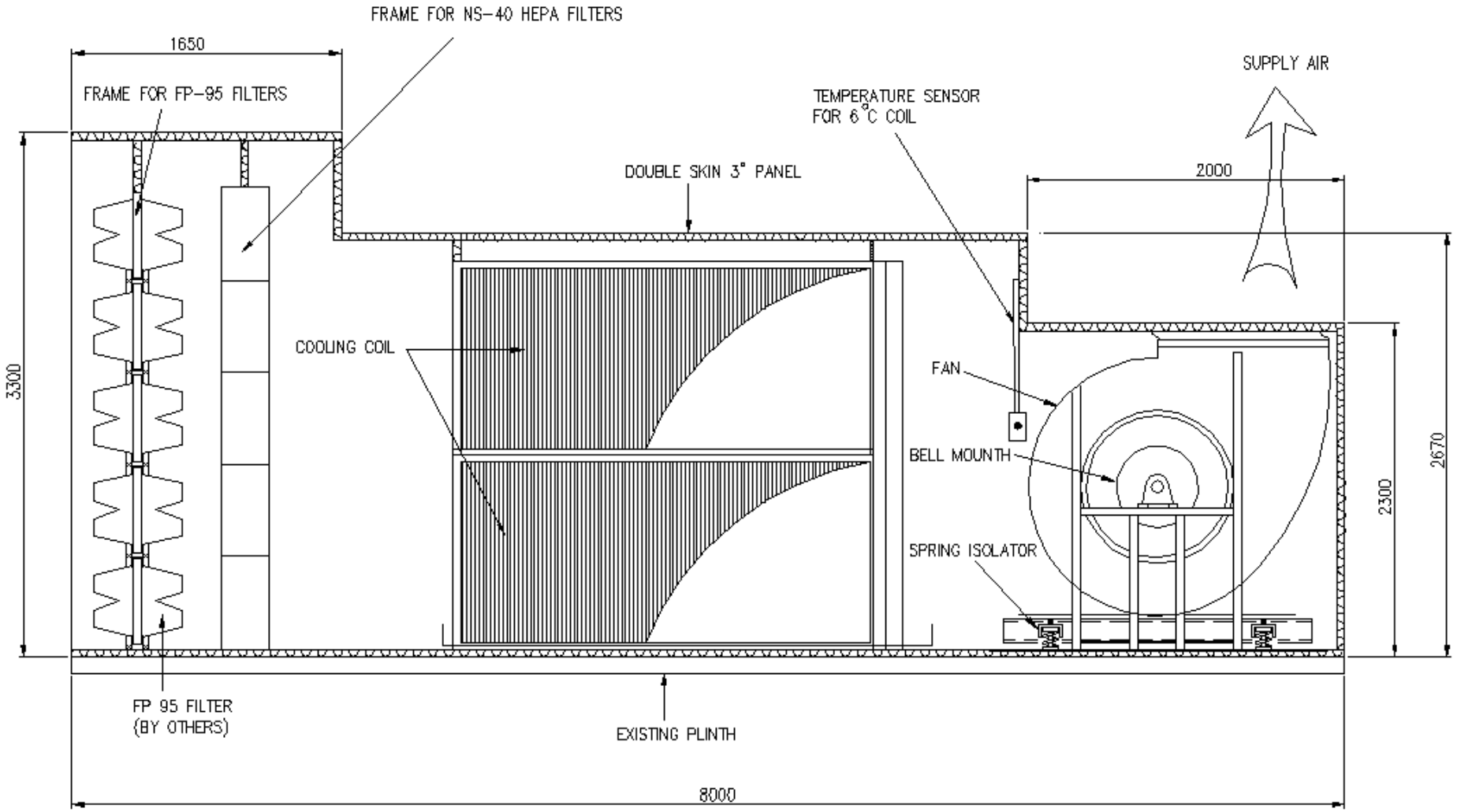
AHU ENERGY RETROFIT

New AHU Plan View



AHU ENERGY RETROFIT

New AHU Section

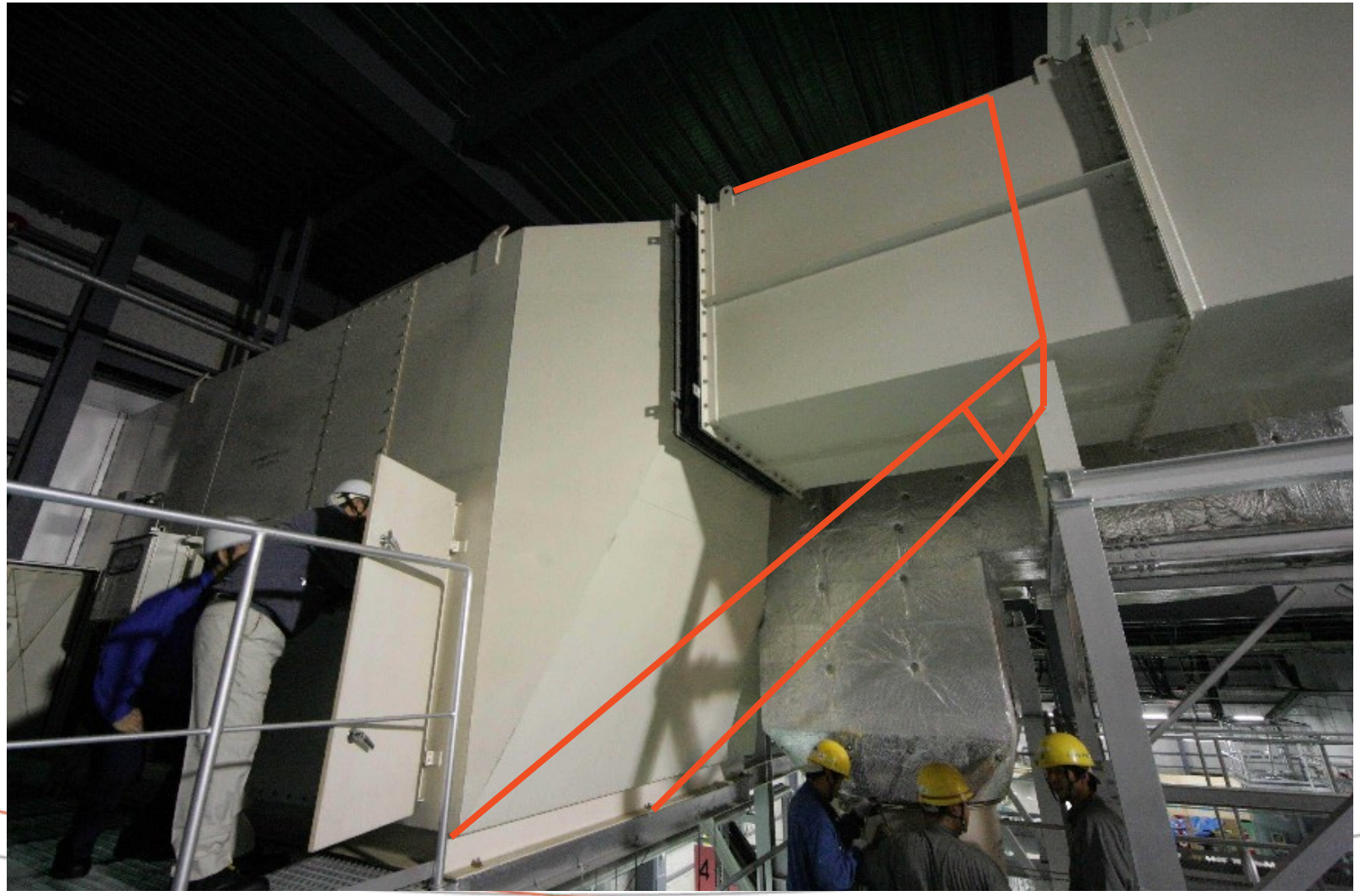


AHU ENERGY RETROFIT

Executive Summary

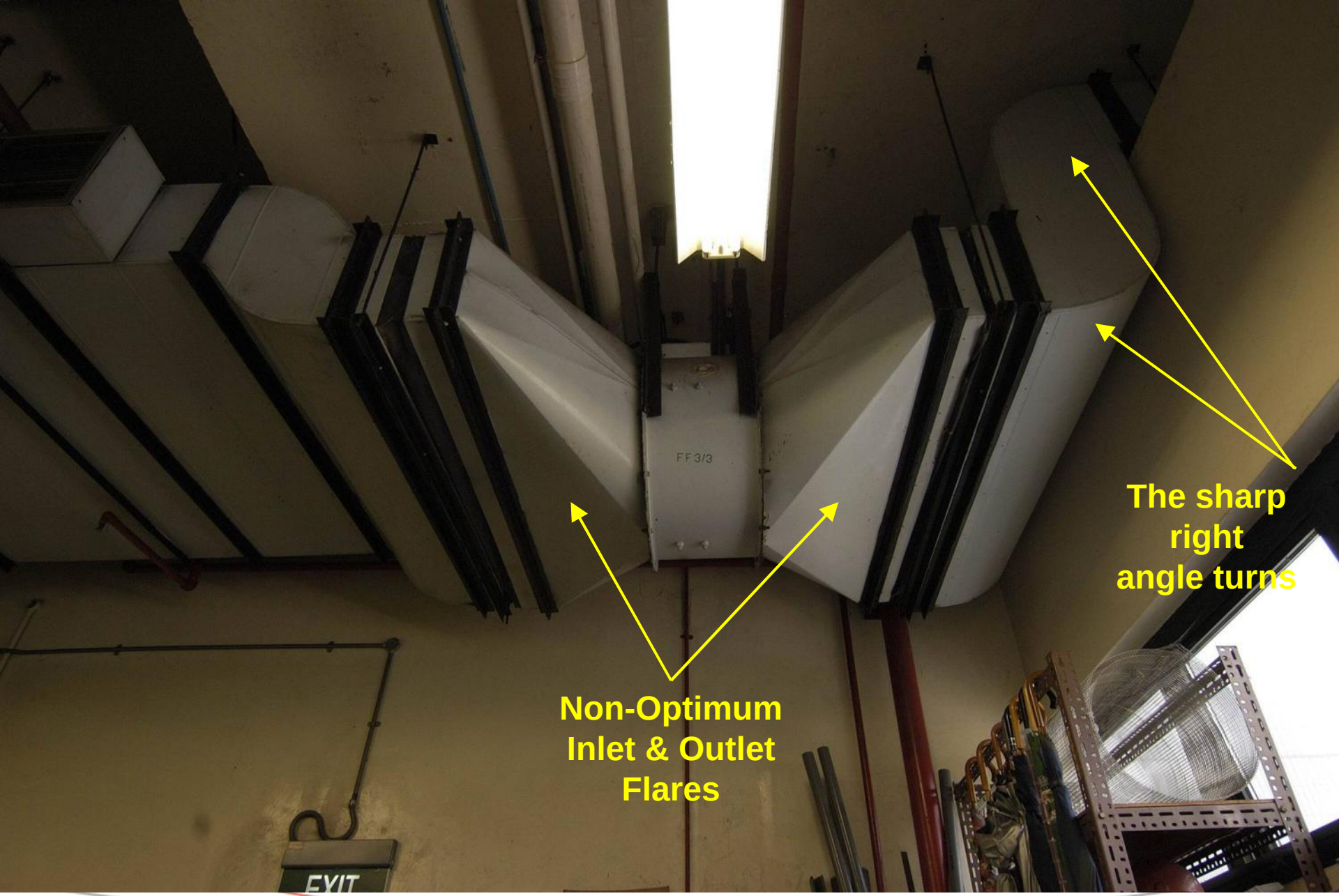
	OLD and NEW AHU PERFORMANCE			
#	**AHU Parameter (100% fresh air):**	**Unit**	**OLD AHU**	**NEW AHU**
1	Total cooling capacity	Ton refrigerant	340	354
2	Chilled water supply temperature	Degree C	6	15-pre-cool, 6-final cooling
3	Chilled water temperature rise	Degree C	5.5	11
4	Fan power consumption	KW	35	7
5	Chiller power consumption	KW	212	170
6	AHU efficiency	KW/Ton	0.1	0.02
	SAVINGS			
#	**Savings (for 2 units):**	**kW**	**%**	**$Sin/Year**
1	Fan power consumption	56	80	72,800
2	Chiller power consumption	84	20	109,200
3	Total	140		182,000
	Payback period of investments 1.9 years			

Optimising Filter Box for GT1




42


TEL


FF 3/3
EXIT
The sharp right angle turns
Non-Optimum Inlet & Outlet Flares

CASE STUDY -- Raffles City

Replacement of AHU at office tower

SUMMARY:

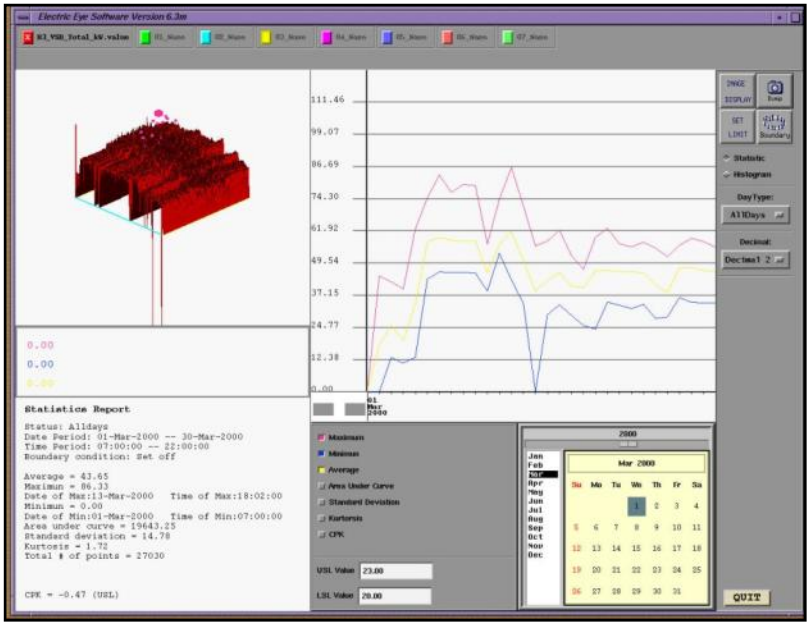
Target operating cost reduction of 50% or more (from 16kW to 8kW)

Improvement of AHU performance

2001 - Energy Project in Malaysia

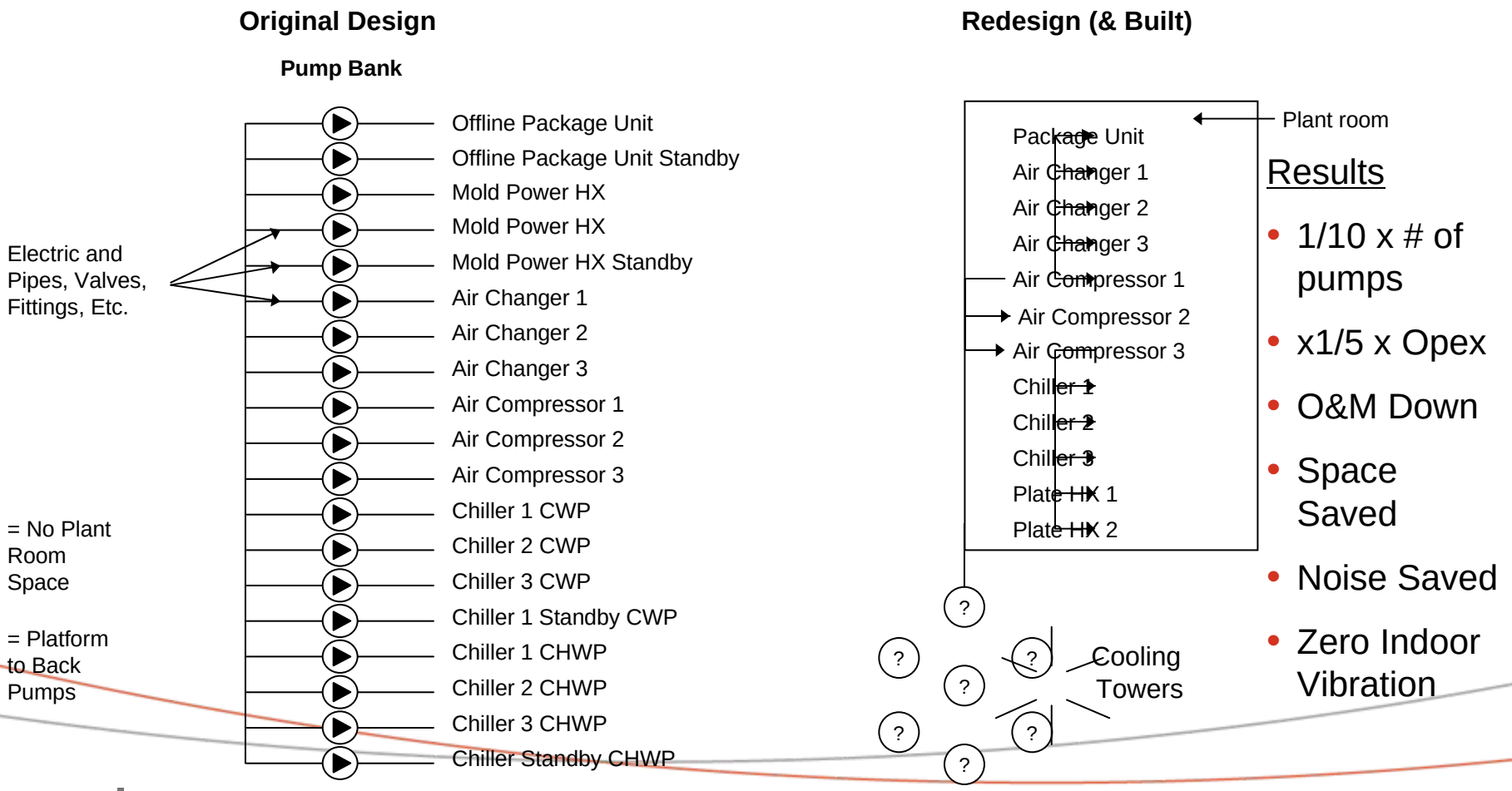
Inefficient Design is replaced by efficient and simple design with proper controls

Energy savings of 90% of total electricity Air Handling Unit electricity use with additional 180 RT on top of original design tonnage. Production room specs met without fail! RM 350,000 per annum savings on RM 900,000 investment!



Simplify pumps and pipes

AT&T Consumer Products (Thailand)



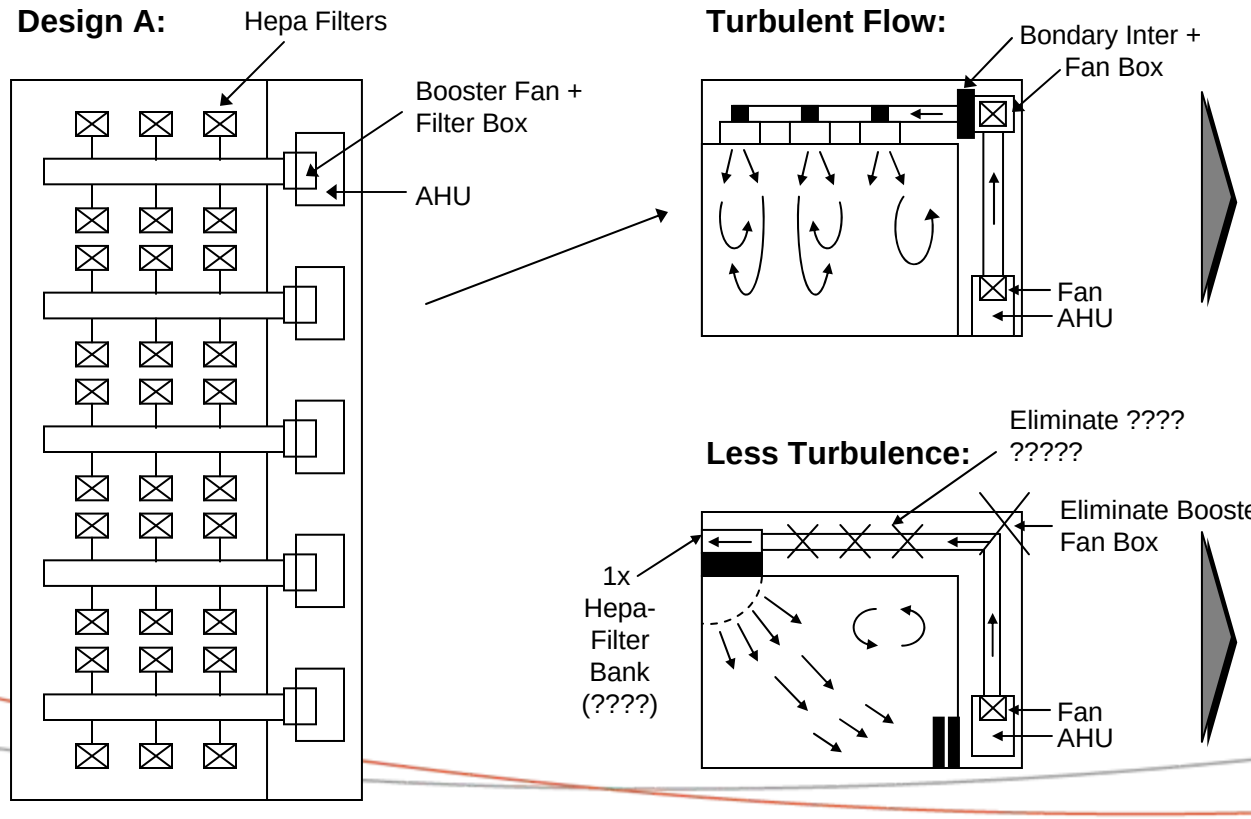
Results

- 1/10 x # of pumps
- x1/5 x Opex
- O&M Down
- Space Saved
- Noise Saved
- Zero Indoor Vibration

Negawatt thinking--Reduce Friction, reduce cost

Becton Dickinson

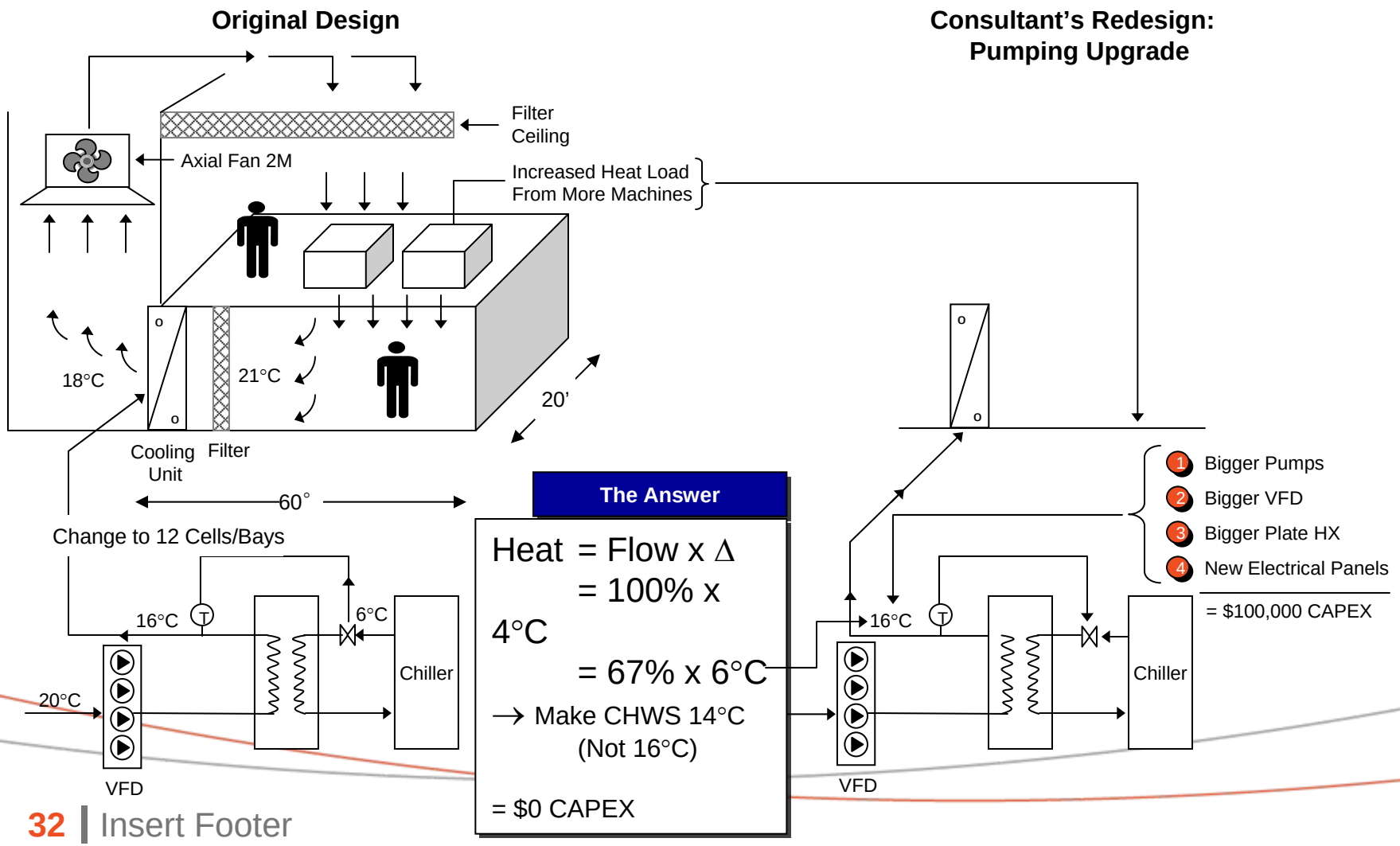
(2) Room facility for injection molding (China) to meet new Chinese GMP-practice



- Higher Capex
- Higher Opex
  - Power
  - O&M

- Low Capex
- Low Opex
  - Less Cooling
  - Less Fan Power

Negawatt thinking--Cooling plant (Phoenix)



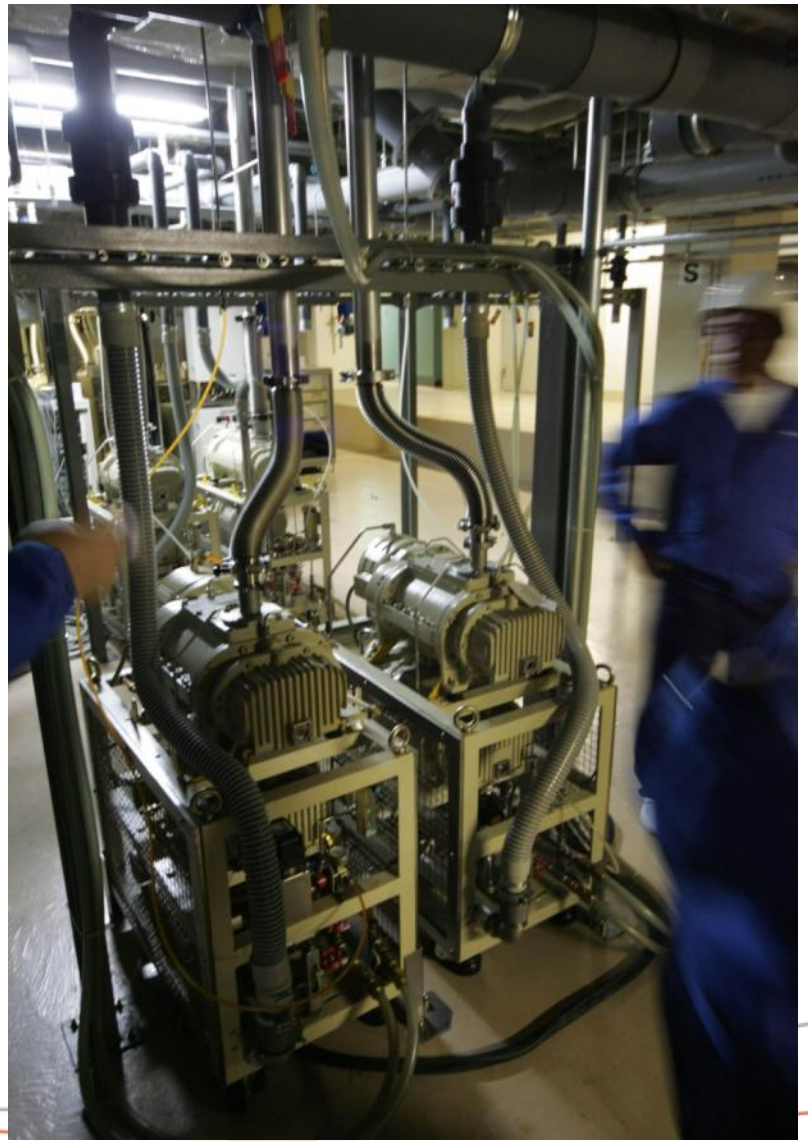
Optimising Fluid Movement

1. >250 Vacuum Pumps

- Presently using 13°C Cooling water, >150° kW pumps
- Constant water flow

- Specs is <30°C inlet water, <40°C outlet water
- Convert to variable temperature, variable flow

- Savings on chiller + Pumps >170 kW.



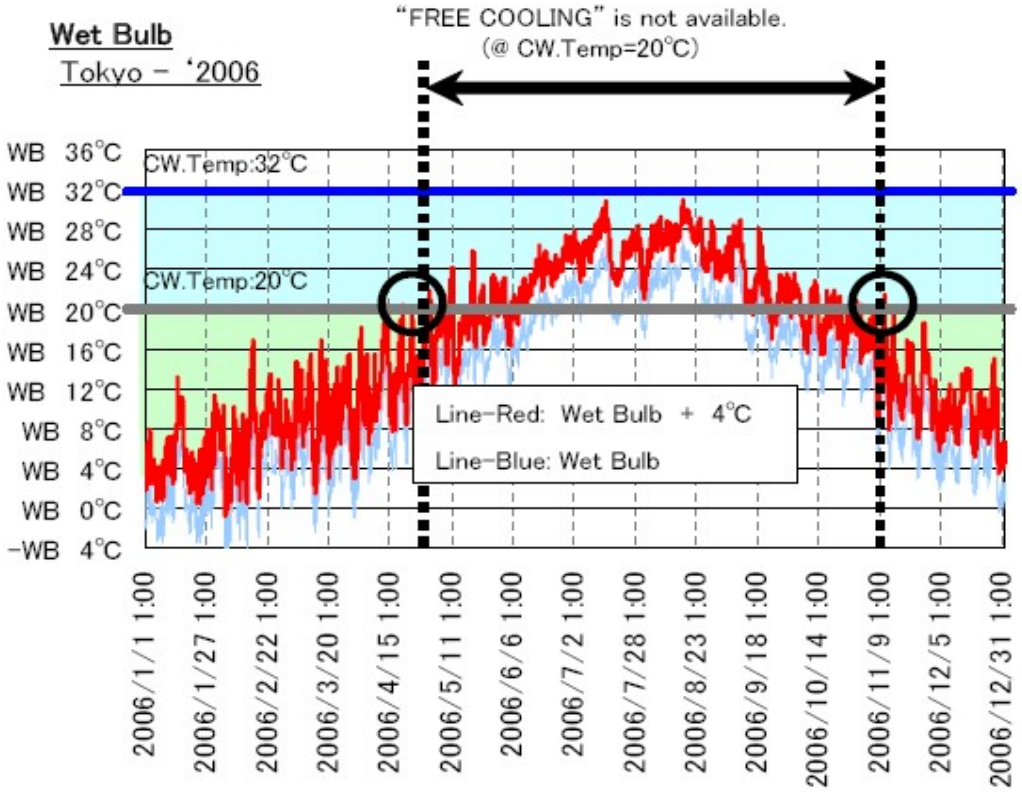
Process Cooling Inlet Water Temperature Higher

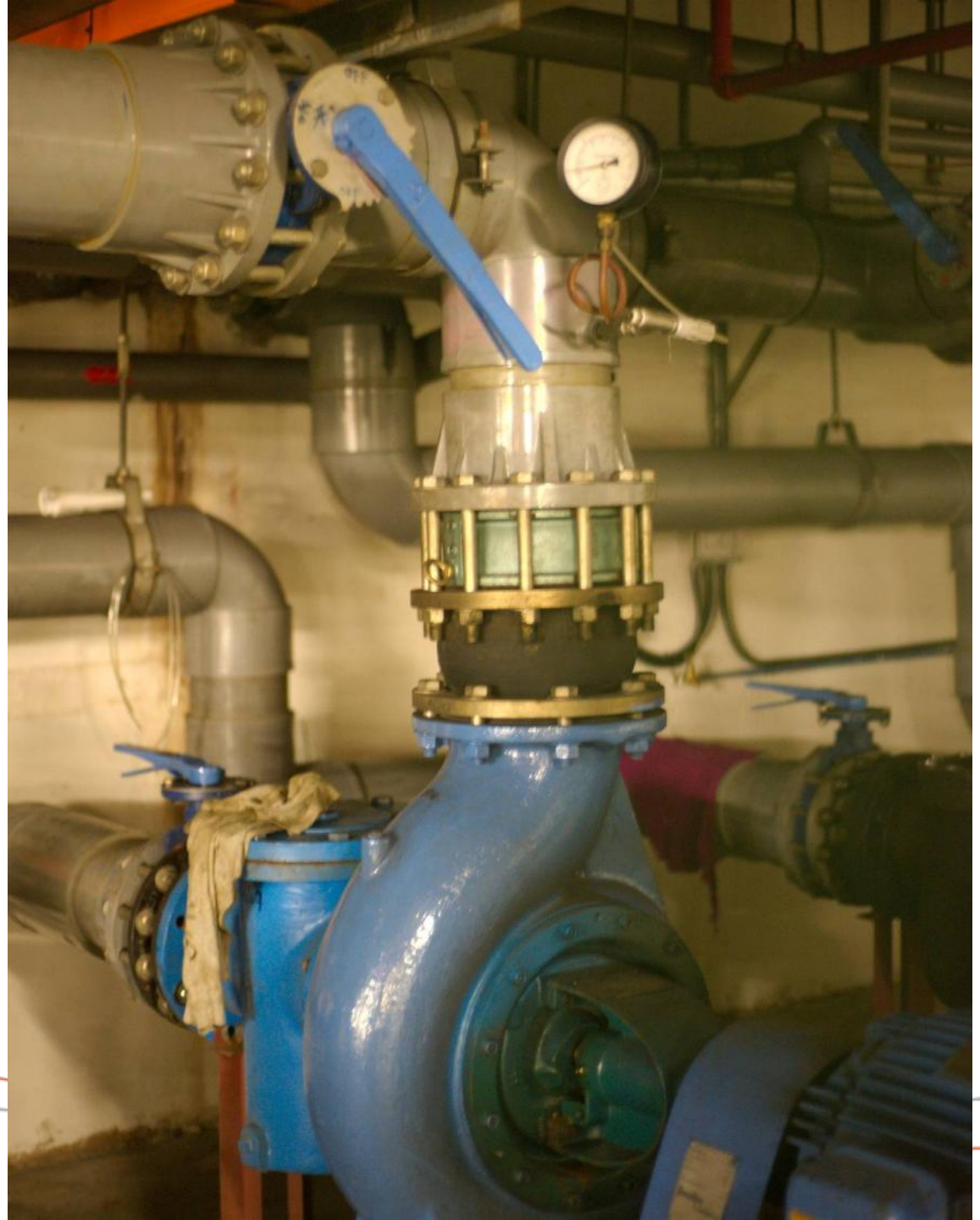
The effect of PCW temperature from 20℃ to 32℃

The PCW inlet temperature 32℃ can be always cooled in all year around by the atmospheric cooling (free cooling)

→ The cooling by the chiller becomes unnecessary.

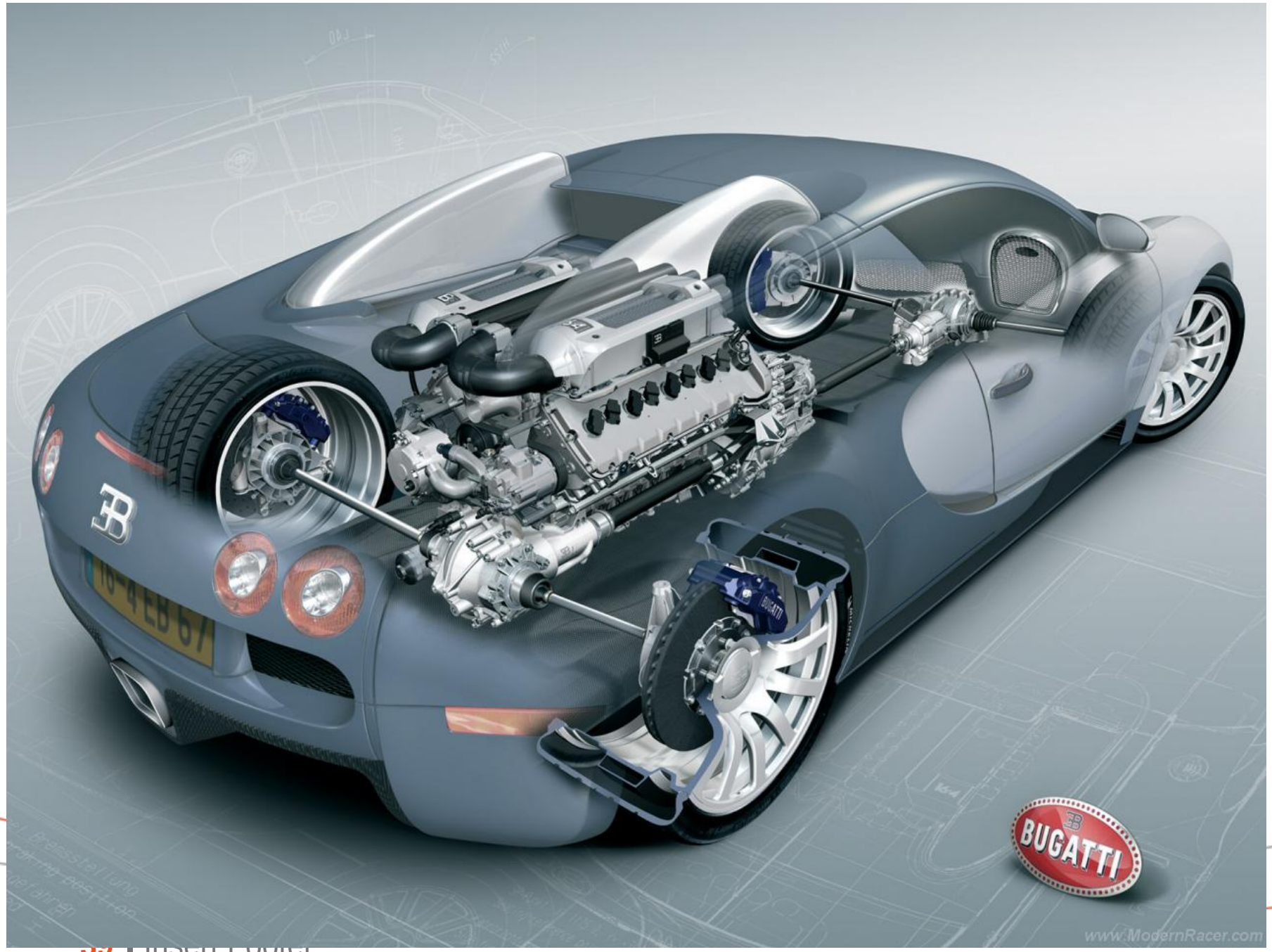
→ Because the heat load of cooling water is large (accounts for 30 - 50 % of the whole factory), large energy saving effect is possible

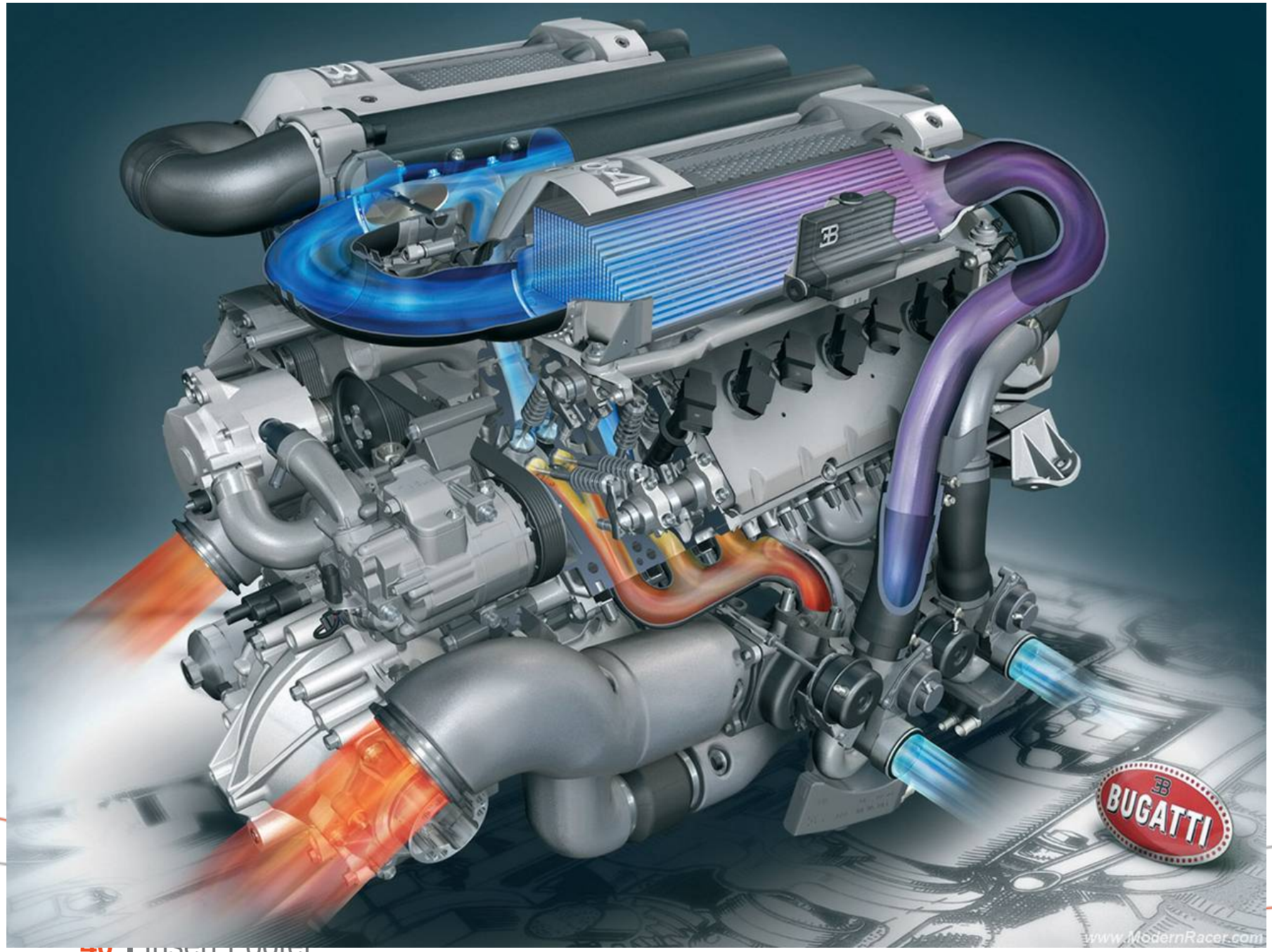




Incorrect Piping Layout 1


2006 Bugatti Veyron 16/4
http://www.bugatti-veyron-16-4.com


BUGATTI
www.ModernRacer.com


BUGATTI
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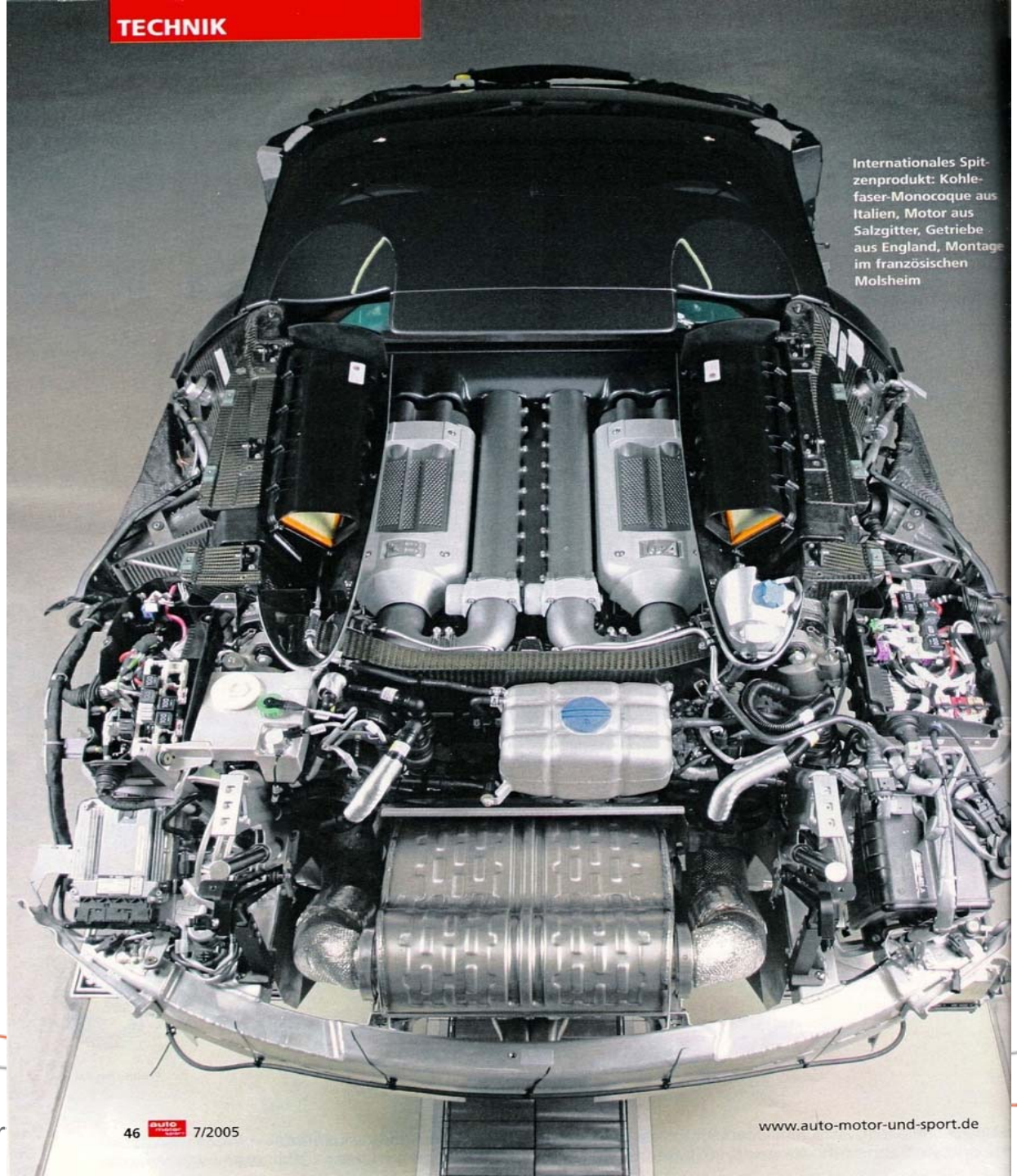


Internationales Spitzenprodukt: Kohlefaser-Monocoque aus Italien, Motor aus Salzgitter, Getriebe aus England, Montage im französischen Molsheim

sed. It's easily the best steering ncountered on any car from the roup, and it kept reinforcing the ring feeling of connectedness. ne was tight if we were going to re than take pictures, so I headed direction of the nearest autostrada, ed above on 650-foot-high pillars gging the northern coastline. A g access road took me onto the first 500, then 600 hp were brought into play. There was no time to think—the car simply rocketed into the blackness of a tunnel. I caught sight of 140 mph on the tiny speedo; this was insane. Short seconds later, I burst back into the sunlight, and a touch on the right paddle slipped yet another cog into play without any pause massive tires and the carbon fiber body.

I was cruising at 130 mph in fourth, with barely 200 hp being called on, according to the power indicator. The Metcalfe brain computed that this meant there's around 800 hp waiting in the wings. Introducing the throttle to the carpet again gravelly as the revs ro the acceleration hit, in hurricane force as the through 900 hp and lu 1001-hp marker. This new dimension of acc four turbos whistled b red line approached, a fixed on a previously r that was fast approac

WhyTwin Temperature CHW Loops ?

---In 1994, proposed to STMicro Singapore, as part of CFC chiller replacement project

---Minus point is extra piping for 12 ~ 15 degC high temp loop, existing 6degC piping loop

---Very strong plus point is large efficiency gains, chiller <0.4 kW/RT, chiller plant < 0.48 kW/RT

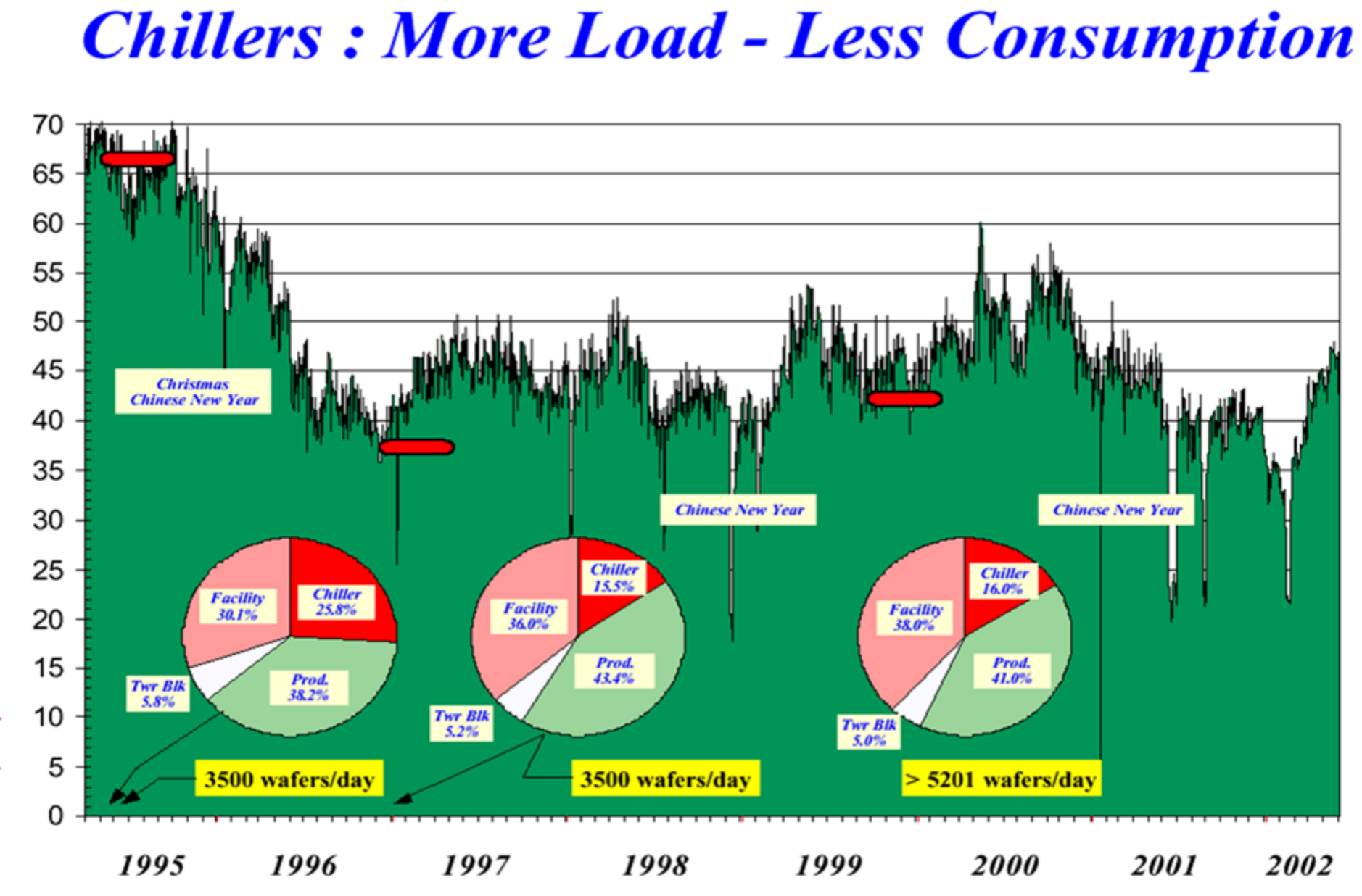
---6 degC chiller plant <0.6 k/RT possible

---10,000 RT average load @ 15c/kWh, improve from 0.7 kW/RT to 0.48 kW/RT saves US$ 2.9 million pa.

---High temp chiller cheaper than low temp chiller, ~ 30% in 1995

STMicroelectronics - Ang Mo Kio

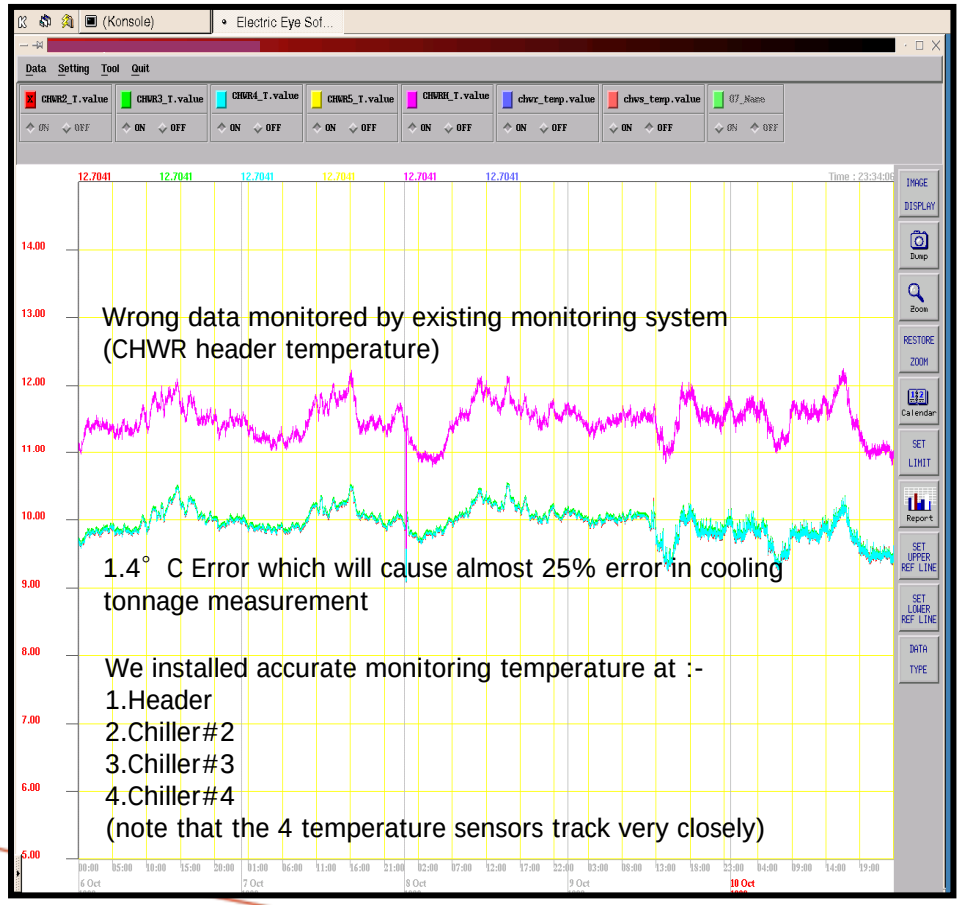
TwinTemperature Loop STMicro 1995



The Cost of Measurement Error

kW/Ton	True Value	5% error	10% error
Existing	1.000	1.05	1.10
Retrofit	0.700	0.665	0.63
Savings	0.300	0.385	0.47
% Savings	30%	36.7%	42.7%
Annual Saving ($)	$100,000	$122,000	$143,000
Reference ($)	0	-$22,000	-$43,000

Example of in-accurate sensor reading in a Semiconductor Factory



Wrong data leading to wrong decision

Action:
Facility people sees high CHWR~12C,more than 100% Load of 2-chillers from BAS-display

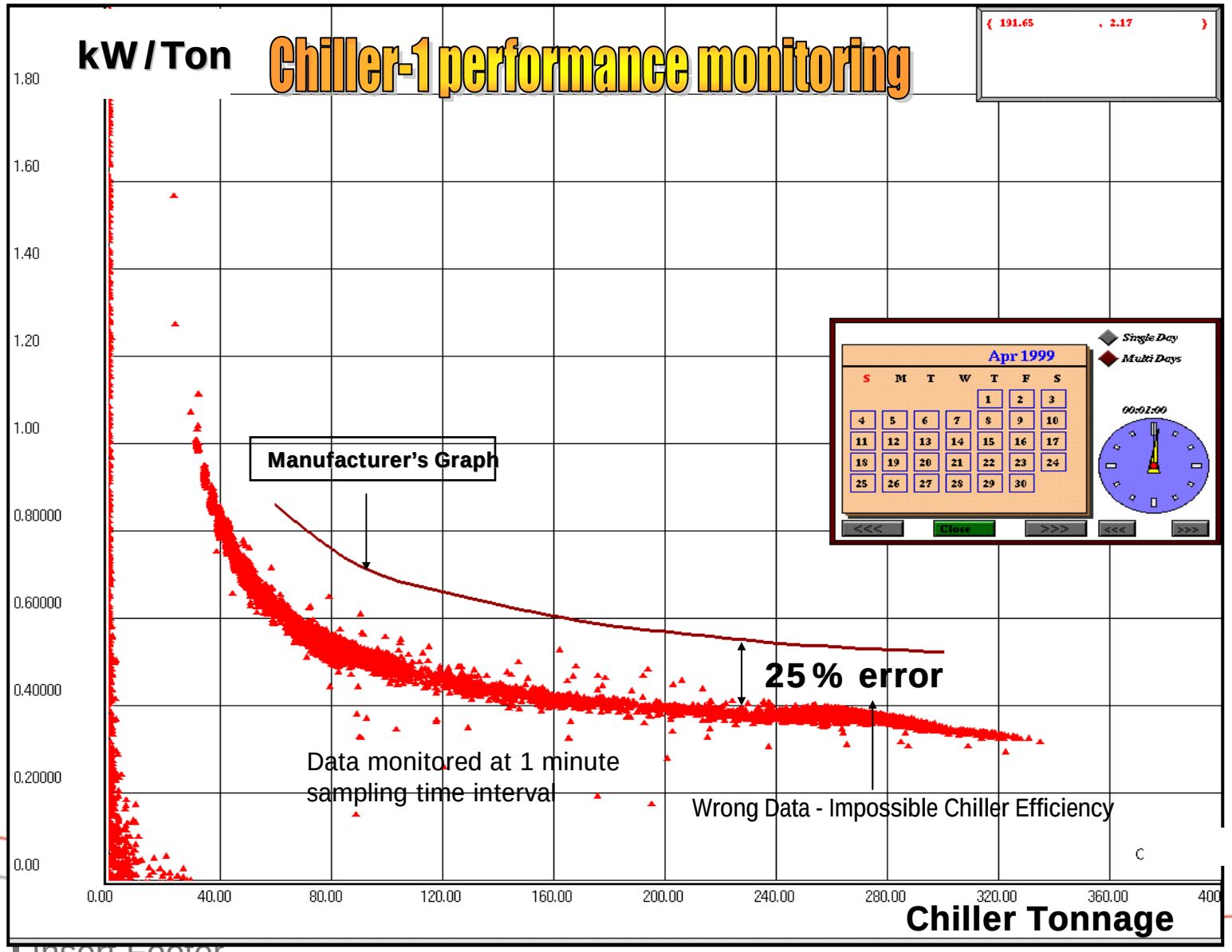
Fact:
Wrong reading on CHWR
Wrong calculation on tonnage

Action
Turn on 3rd chiller and observe 100%load displayed on micro-panel of all chillers

Fact :
Display on micro panel
100% electrical ≠100% cooling load Chiller2(520RT)
100%electrical load but only 50% cooling part load and operating around 1.35kW/RT

Waste of 400kW power - 3,456,000kWh
$320,000 electrical bill per year

In-accurate Sensors and Monitoring System



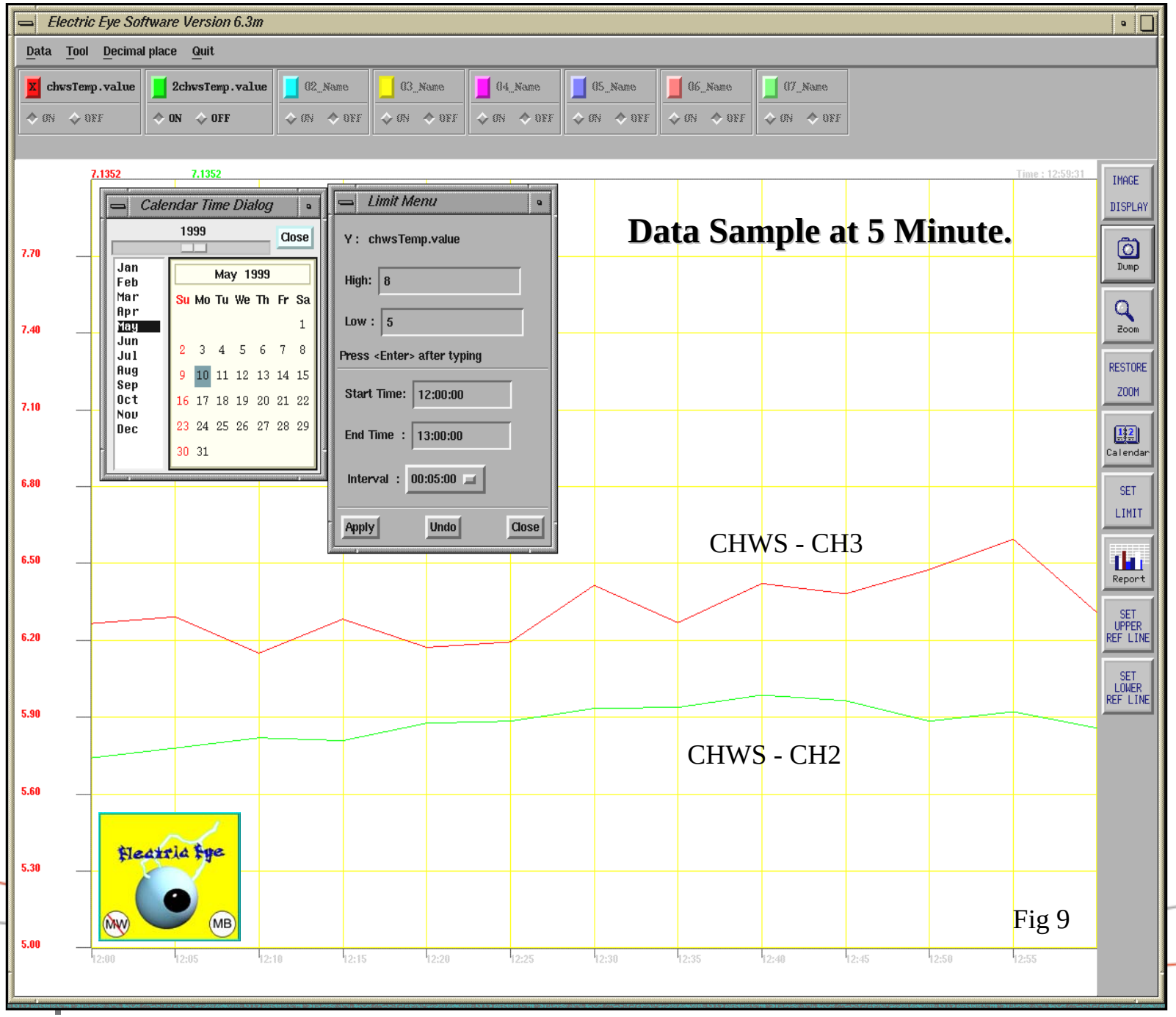

Electric Eye Software Version 6.3m
Data
Tool
Decimal place
Quit
chwsTemp.value
2chwsTemp.value
02_Name
03_Name
04_Name
05_Name
06_Name
07_Name
ON
OFF
Calendar Time Dialog
1999
Close
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
May 1999
Su Mo Tu We Th Fr Sa
Limit Menu
Y : chwsTemp.value
High: 8
Low : 5
Press <Enter> after typing
Start Time: 12:00:00
End Time : 13:00:00
Interval : 00:05:00
Apply
Undo
Close
Data Sample at 5 Minute.
CHWS - CH3
CHWS - CH2
IMAGE DISPLAY
Dump
Zoom
RESTORE ZOOM
Calendar
SET LIMIT
Report
SET UPPER REF LINE
SET LOWER REF LINE
7.70
7.40
7.10
6.80
6.50
6.20
5.90
5.60
5.30
5.00
12:00
12:05
12:10
12:15
12:20
12:25
12:30
12:35
12:40
12:45
12:50
12:55

Fig 9

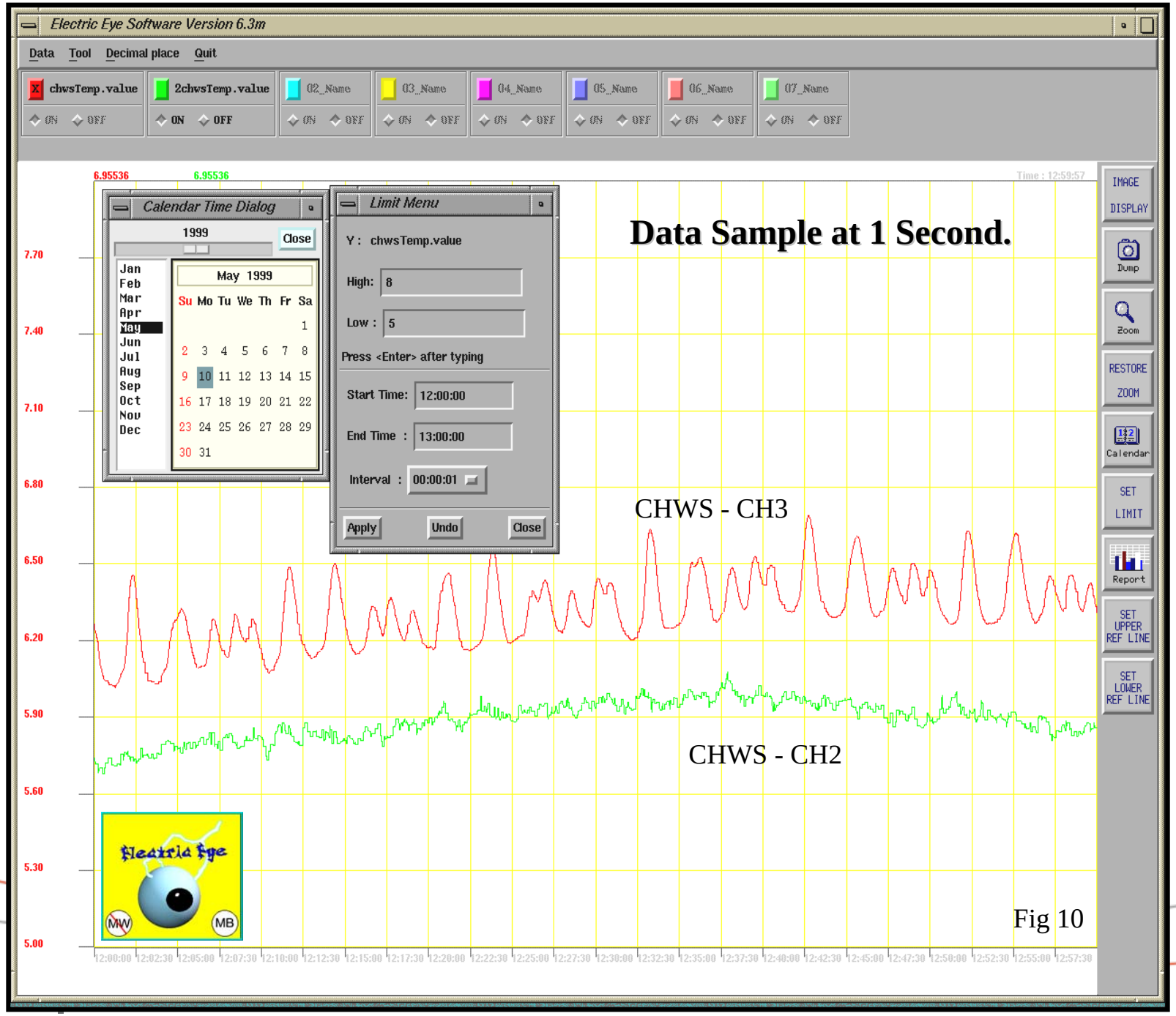

Electric Eye Software Version 6.3m
Data
Tool
Decimal place
Quit
chwsTemp.value
2chwsTemp.value
02_Name
03_Name
04_Name
05_Name
06_Name
07_Name
ON
OFF
6.95536
6.95536
Time : 12:59:57
Calendar Time Dialog
1999
Close
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
May 1999
Su Mo Tu We Th Fr Sa
1 2 3 4 5 6 7 8
9 10 11 12 13 14 15
16 17 18 19 20 21 22
23 24 25 26 27 28 29
30 31
Limit Menu
Y : chwsTemp.value
High: 8
Low : 5
Press <Enter> after typing
Start Time: 12:00:00
End Time : 13:00:00
Interval : 00:00:01
Apply
Undo
Close
Data Sample at 1 Second.
CHWS - CH3
CHWS - CH2
7.70
7.40
7.10
6.80
6.50
6.20
5.90
5.60
5.30
5.00
12:00:00 12:02:30 12:05:00 12:07:30 12:10:00 12:12:30 12:15:00 12:17:30 12:20:00 12:22:30 12:25:00 12:27:30 12:30:00 12:32:30 12:35:00 12:37:30 12:40:00 12:42:30 12:45:00 12:47:30 12:50:00 12:52:30 12:55:00 12:57:30
IMAGE DISPLAY
Dump
Zoom
RESTORE ZOOM
Calendar
SET LIMIT
Report
SET UPPER REF LINE
SET LOWER REF LINE
Electric Eye
MW
MB

Fig 10

Trane Singapore Calibration Lab

Trane Singapore has invested heavily on sensors, instrument, calibration equipment and computers. We are the only Total Performance Energy Service Company in Asia to have such sensors and equipment to do energy jobs.

Calibration Lab

Triple Point Bath

Super Thermometer (1 ppm)

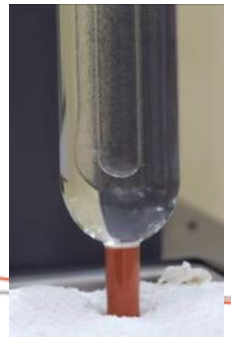
15 ºC Water Bath

Gallium Cell Bath

We hand calibrate our temperature sensors to an uncertainty of ±0.01 ºC

Gallium Cell Bath 29.7646 Deg C

Triple Point Cell (0.01ºC)



Agilent 3458 (81/2 digit)

Typical BAS Sensor Specs

Technical Specifications

TE-6300 Series Temperature Sensors (Part 1 of 2)

Sensor Reference Resistance	**1k ohm Nickel**	1k ohms at 70°F (21°C)
	1k ohm Nickel Averaging	
	1k ohm Platinum	1k ohms at 32°F (0°C)
	100 ohm Platinum Averaging	100 ohms at 32°F (0°C)
	1k ohm Platinum Averaging	1k ohms at 32°F (0°C)
	2.2k ohm Thermistor	2,252 ohms at 77°F (25°C)
	10k ohm Thermistor	10.0k ohms at 77°F (25°C)
Sensor Accuracy	**1k ohm Nickel**	±0.34F° at 70°F (±0.19C° at 21°C)
	1k ohm Nickel Averaging	±3.4F° at 70°F (±1.9C° at 21°C)
	1k ohm Platinum	±0.73F° at 70°F (±0.41C° at 21°C), DIN Class B
	100 ohm Platinum Averaging	±1.0F°at 70°F (± 0.58C° at 21°C)
	1k ohm Platinum Averaging	
	2.2k ohm Thermistor	±0.36F° (±0.2C°) in the range: 32 to 158°F (0 to 70°C)
	10k ohm Thermistor	±0.9F° (±0.5C°) in the range: 32 to 158°F (0 to 70°C)

Yamatake Industrial Grade Sensor

Pipe Temperature Sensor

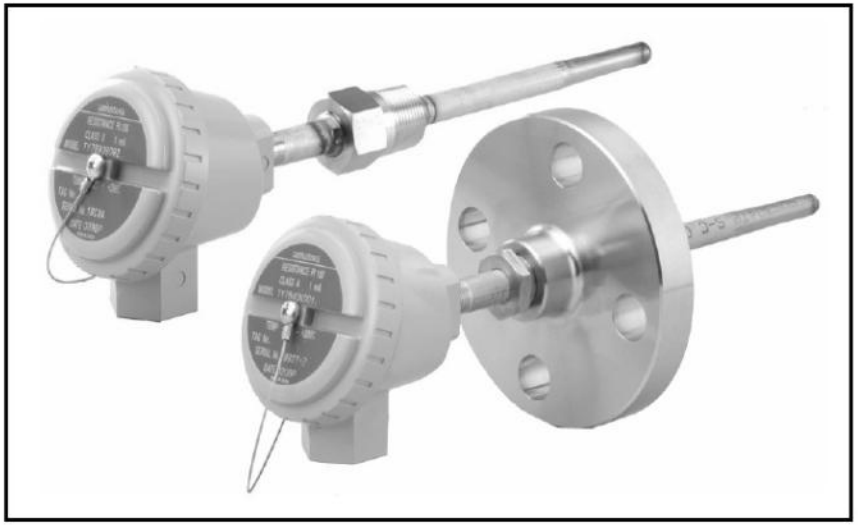
Model TY783

General

Model TY783 is a pipe-mount (insertion type) temperature sensor. Its Pt100 resistance (equivalent to JIS* C1604 Class A) output is used for temperature reading, control, and recording of the media of a pipe, tank, or heat exchanger.

Model TY783 is also applicable to temperature sensing of a duct or chamber.

* JIS: Japanese Industrial Standards



Specifications

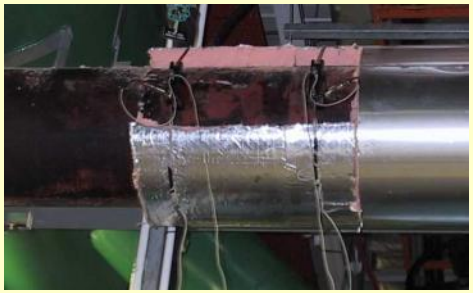
Item	Specification
Sensing range	-50 °C to 200 °C
Applicable measuring fluid	Different depending on the materials of thermowell. Refer to "Corrosiveness of the Sensor Thermowell" section.
Sensing accuracy	± (0.15 + 0.002|t|) °C t: temperature measured
Time constant	Models TY7830A to TY7830F, TY7830J, TY7830K, TY7831A to TY7831F, TY7831J, TY7831K (weld thermowell): Approx. 50 s (in agitated water) Models TY7830G, TY7830H, TY7830M, TY7830N, TY7831G, TY7831H, TY7831M, TY7831N, TY7832G, TY7832H, TY7832M, TY7832N (hollow thermowell): 20 s (in agitated water)


GATE 2

Optimising New Chiller Plant System Efficiency

SCADA Monitoring System

1.Existing SCADA monitoring system does not provide good analysis data



Eg 1.Chiller-2 flow meter

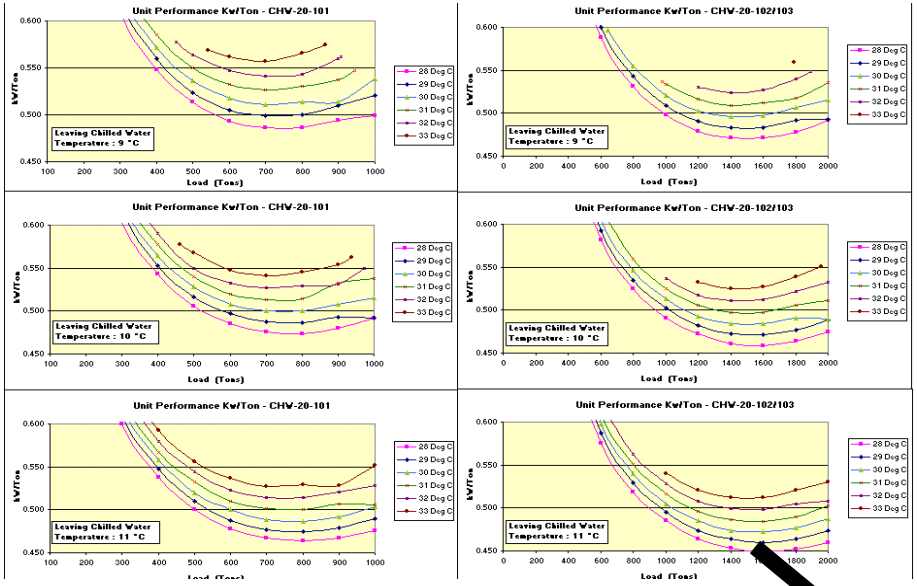
Flow meter +/- 2% error

Existing SCADA Flow meter :

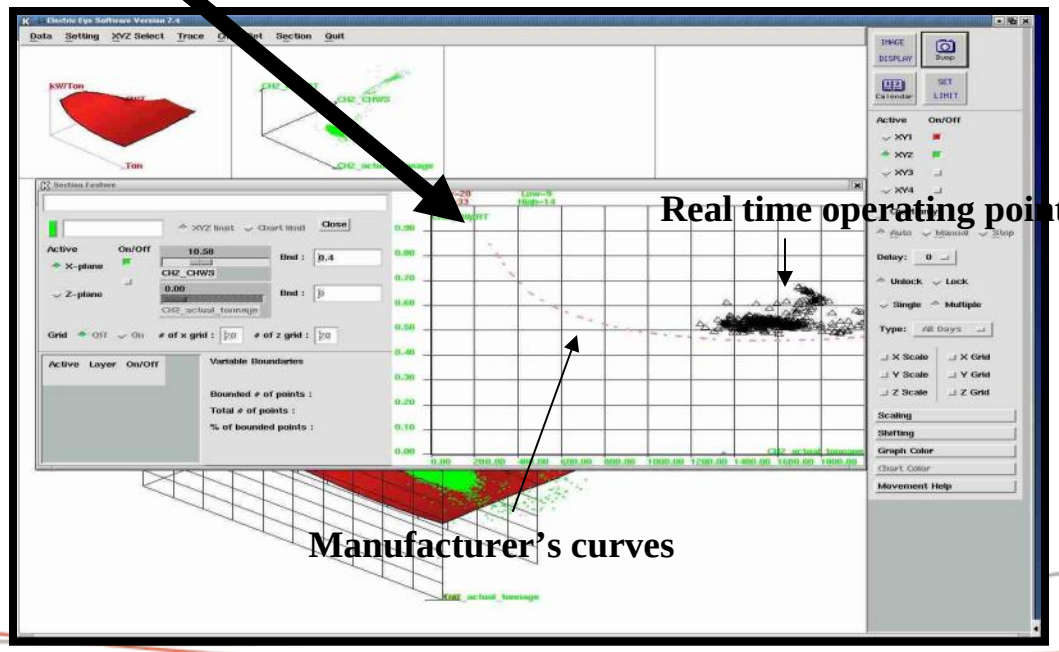
Reading read lower by -23%

(750 usgpm lesser)

Magnetic flow meter should be used (+/-0.5% error)

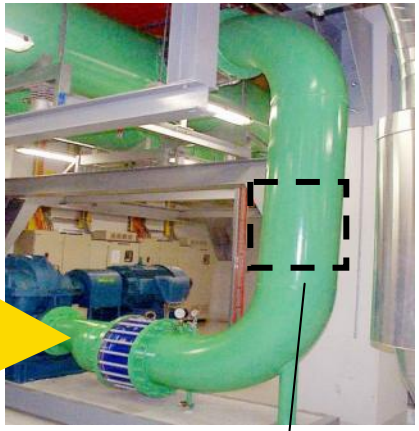


Analyse manufacturing curves vs real time operating points



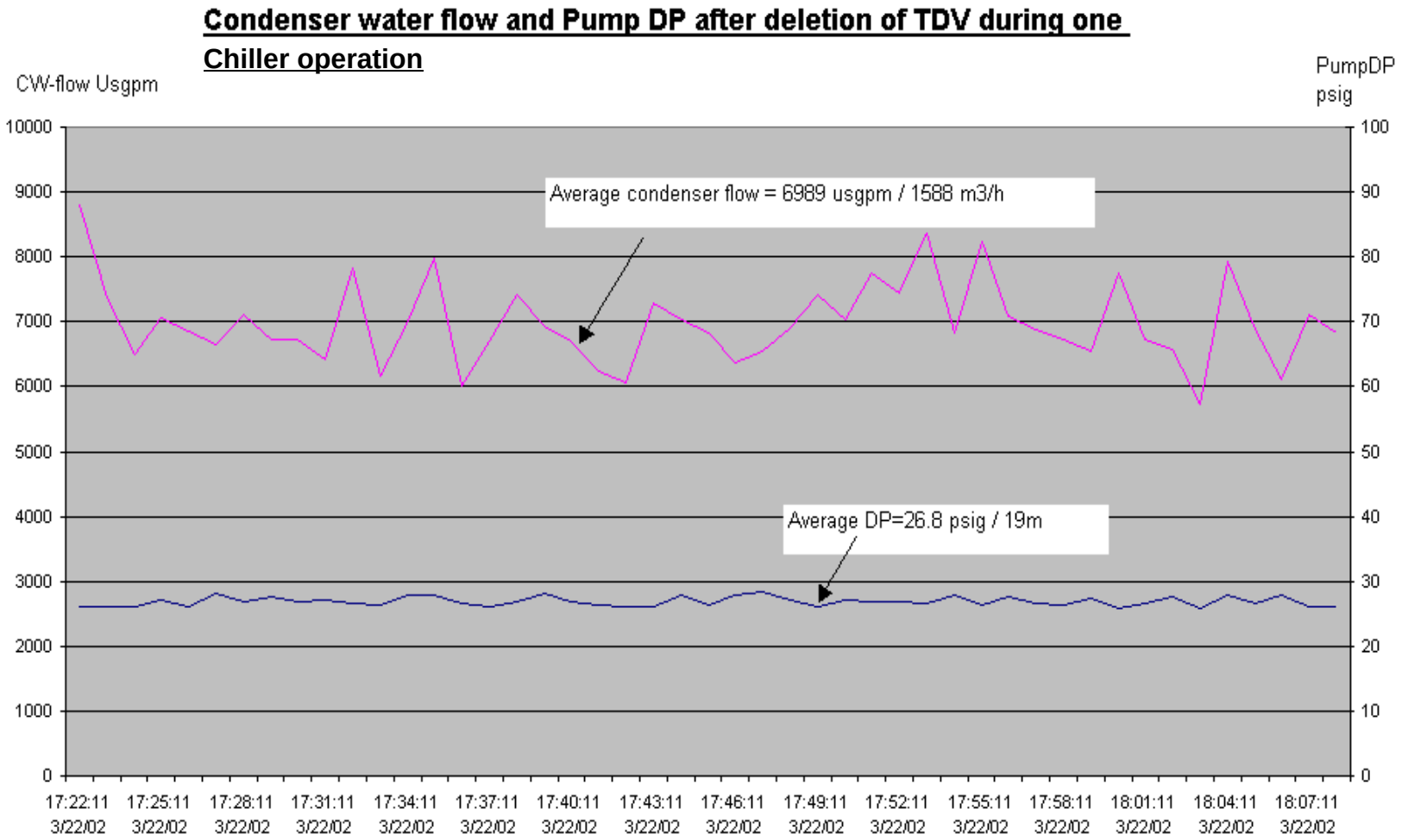
Deletion of triple valve of PMP21-202 during 8 Mar 2002 - 16 Mar 2002

Install new 20" check valve with low friction check-valve and change the pipe to 20"



Deletion of 14" TDV

Result (22Mar2002) : 6989 usgpm (1588 m3/h) / DP=19 m



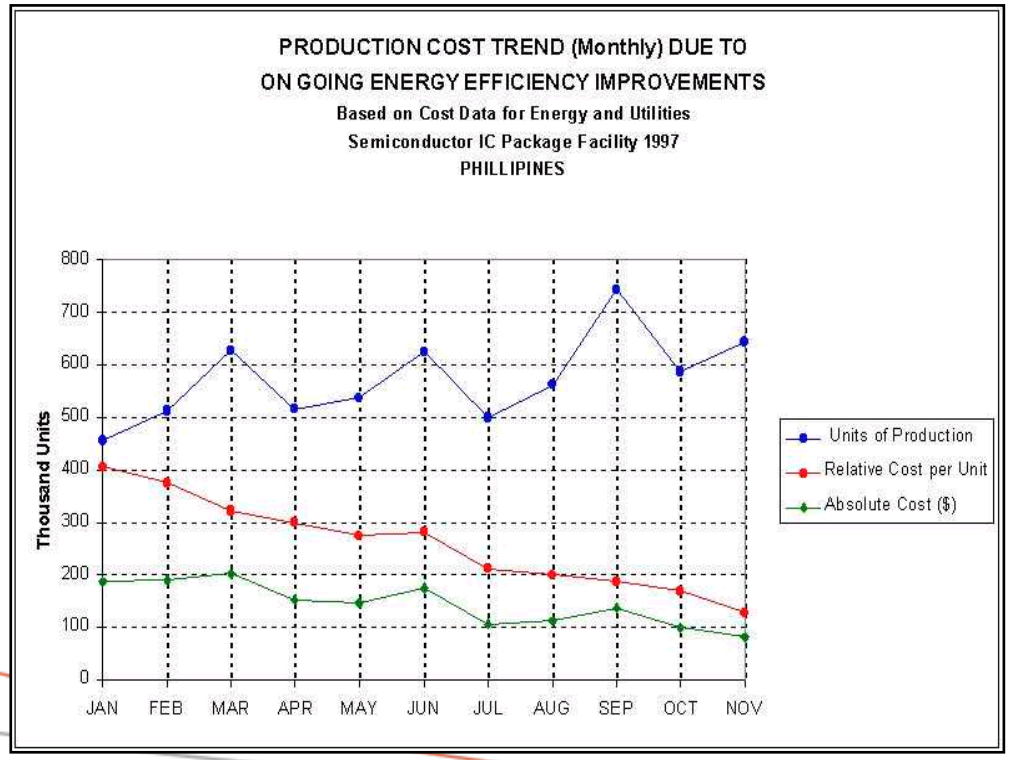
One Chiller Operation Saving Summary

Descriptions	Typical day 14NOV2001	Typical day 7April2002	Power reduction-KW
Chiller RT	2322	2303	
Cooling towers -kW	195	154.22	40.78
Condenser water pumps-kW	167	86	81
Primary chilled water pumps -kW	55.8	36.9	18.9
Secondary chilled water pumps -kW	43.37	48.75	-5.38
Chiller -kW	1237	1023	214
Total Plant kW	1698	1348	350
Plant kW/RT	0.7313	0.585	
Chiller kW/RT	0.532	0.444	
Total power reduction	**350**	**kW**	

Amkor Anam

Power cost per chip produced, saved 37%.

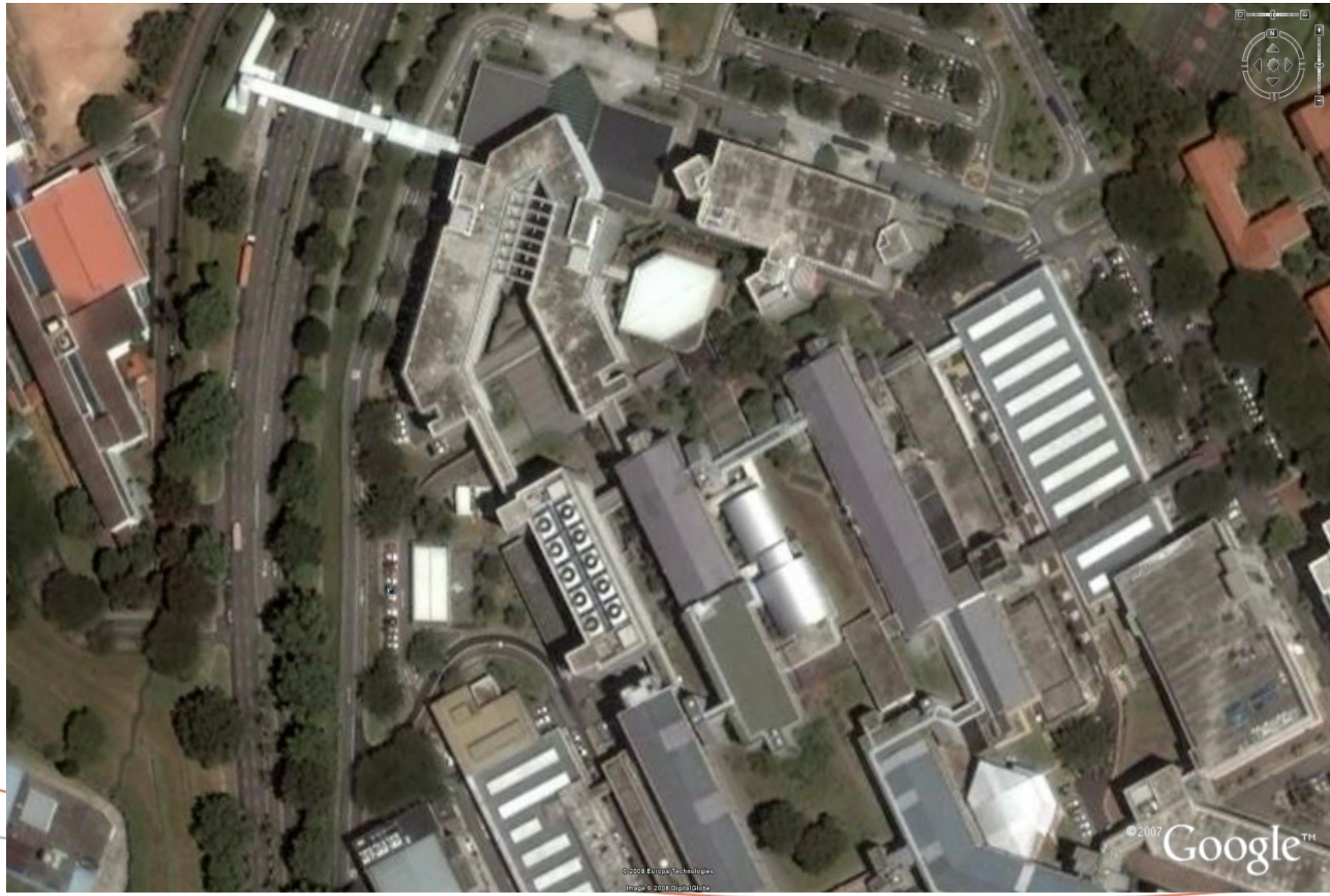
In terms of $ - savings of more than US$2 million annually



Removal of secondary pumps

Installation of high efficiency chillers

Installation of magnetic flow meters and inverters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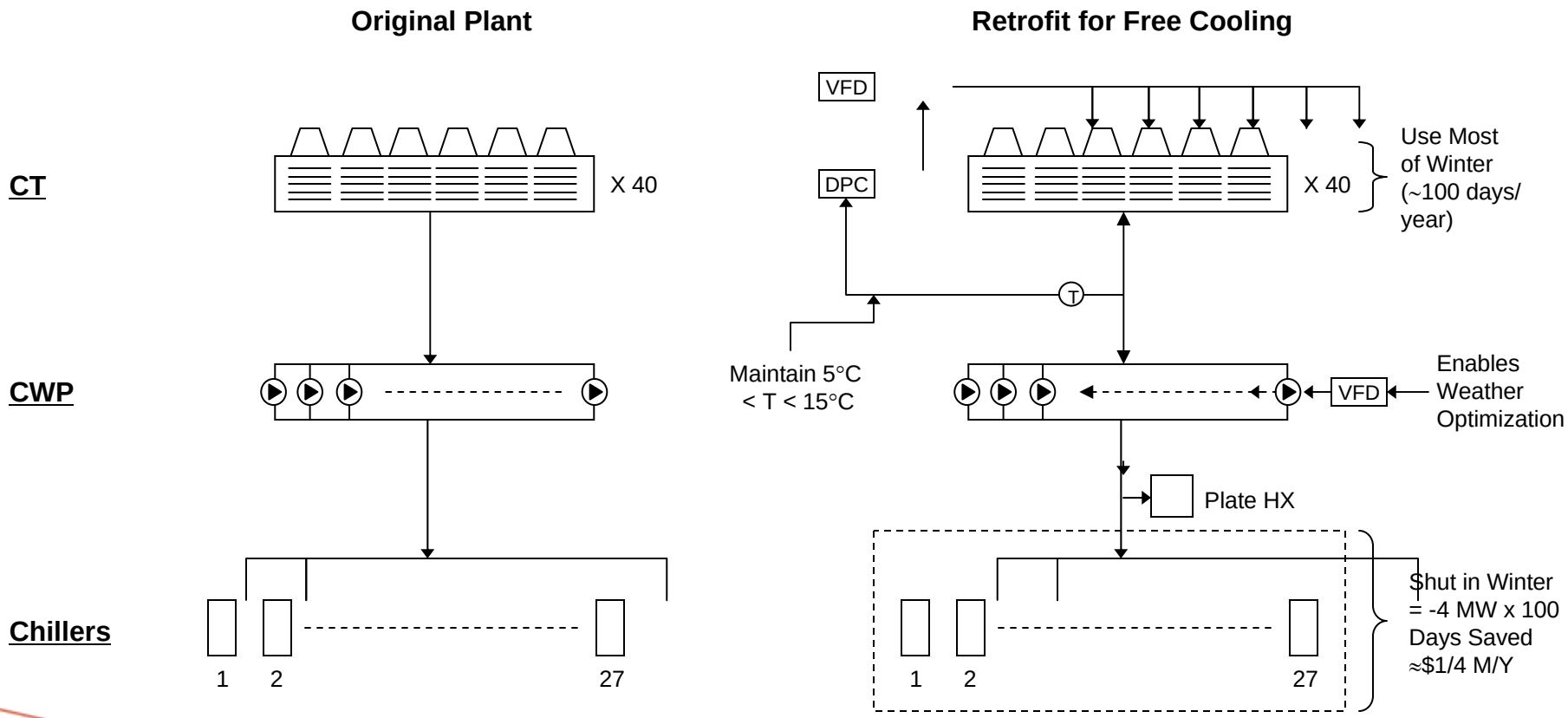
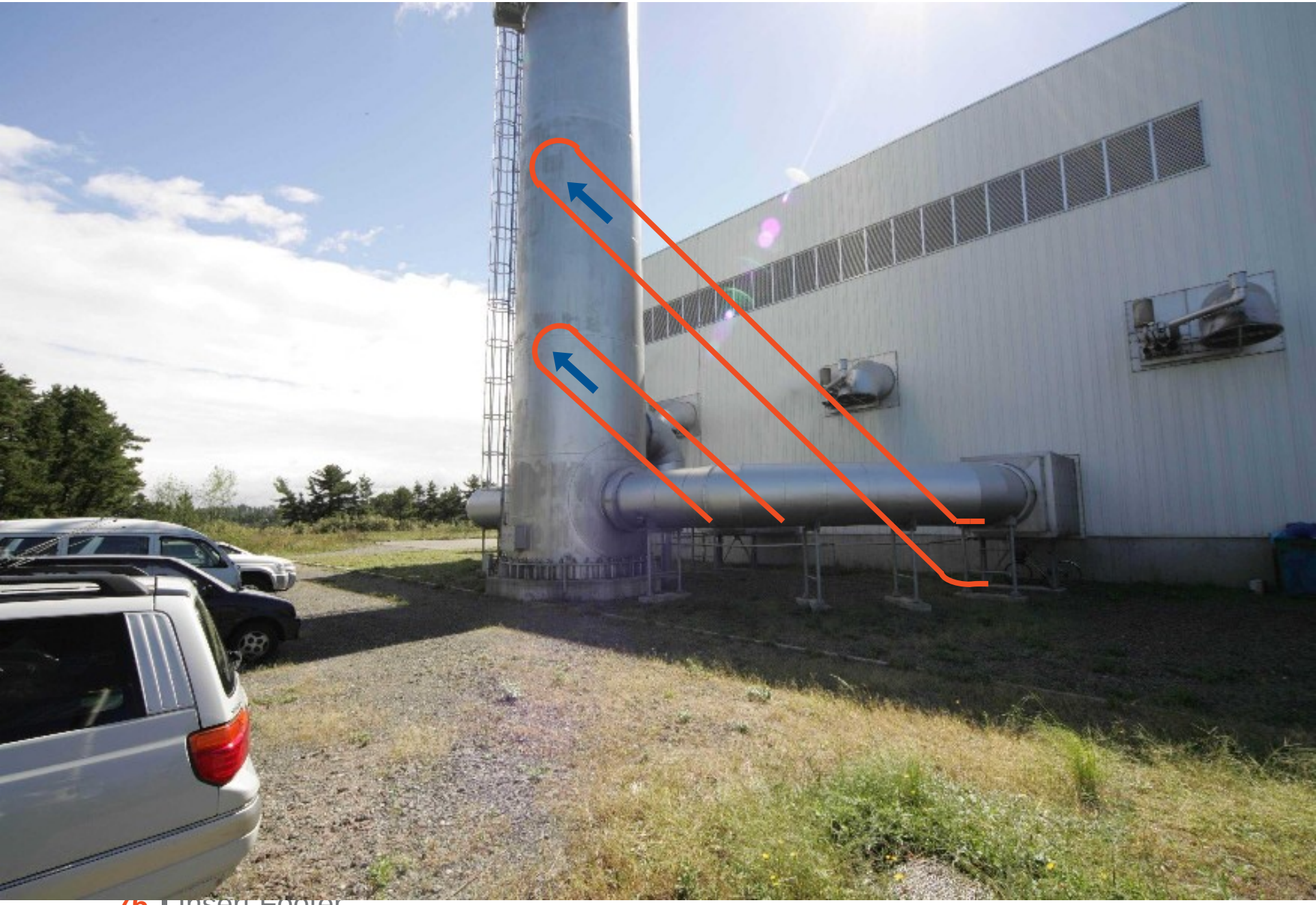
Cooling Tower Bank On Rooftop

Spacing Issue Between Cooling Towers


60
40
80
20
100
0
120
8968
VDO

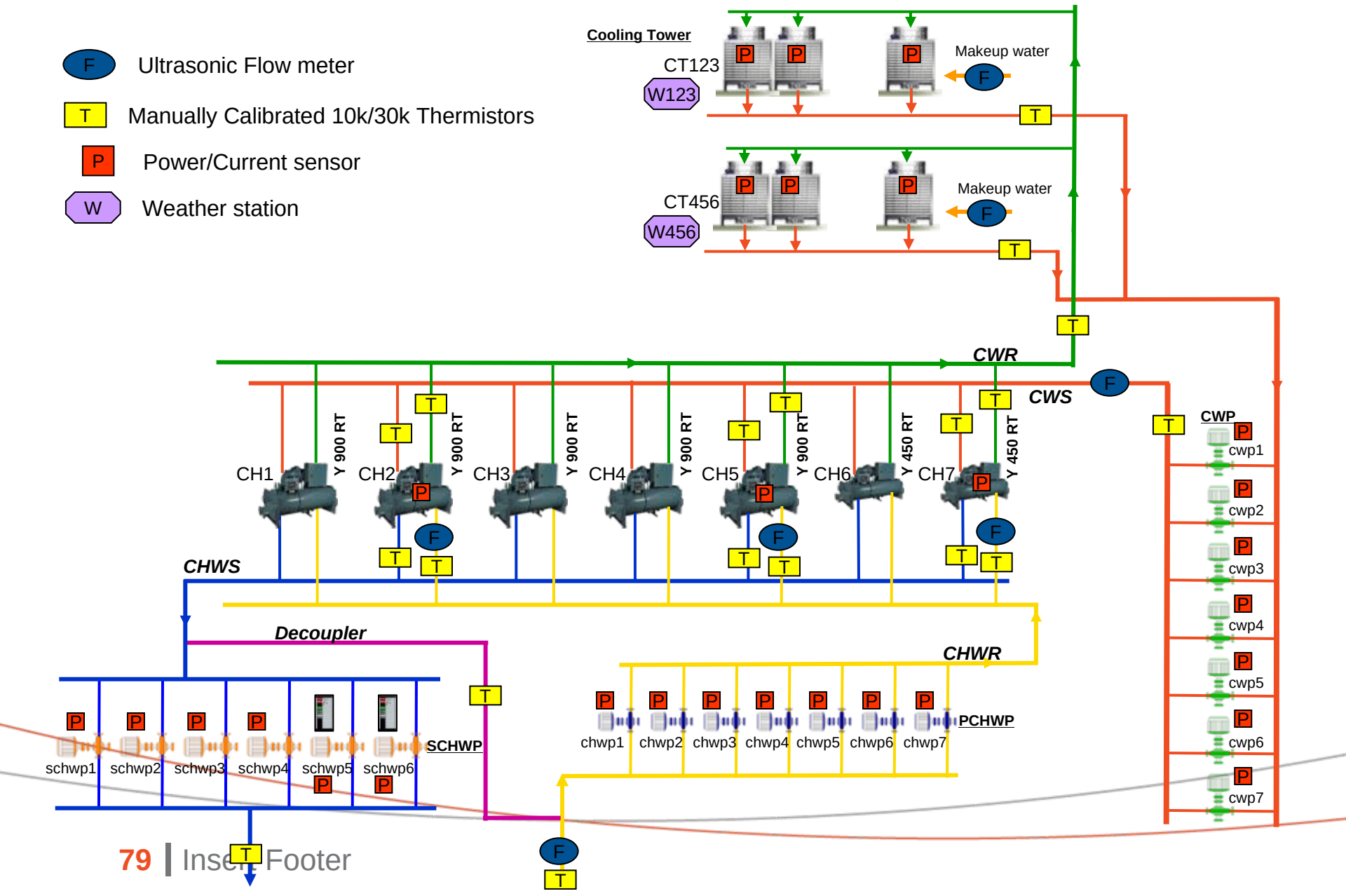
Free Cooling Semiconductor Plant Italy



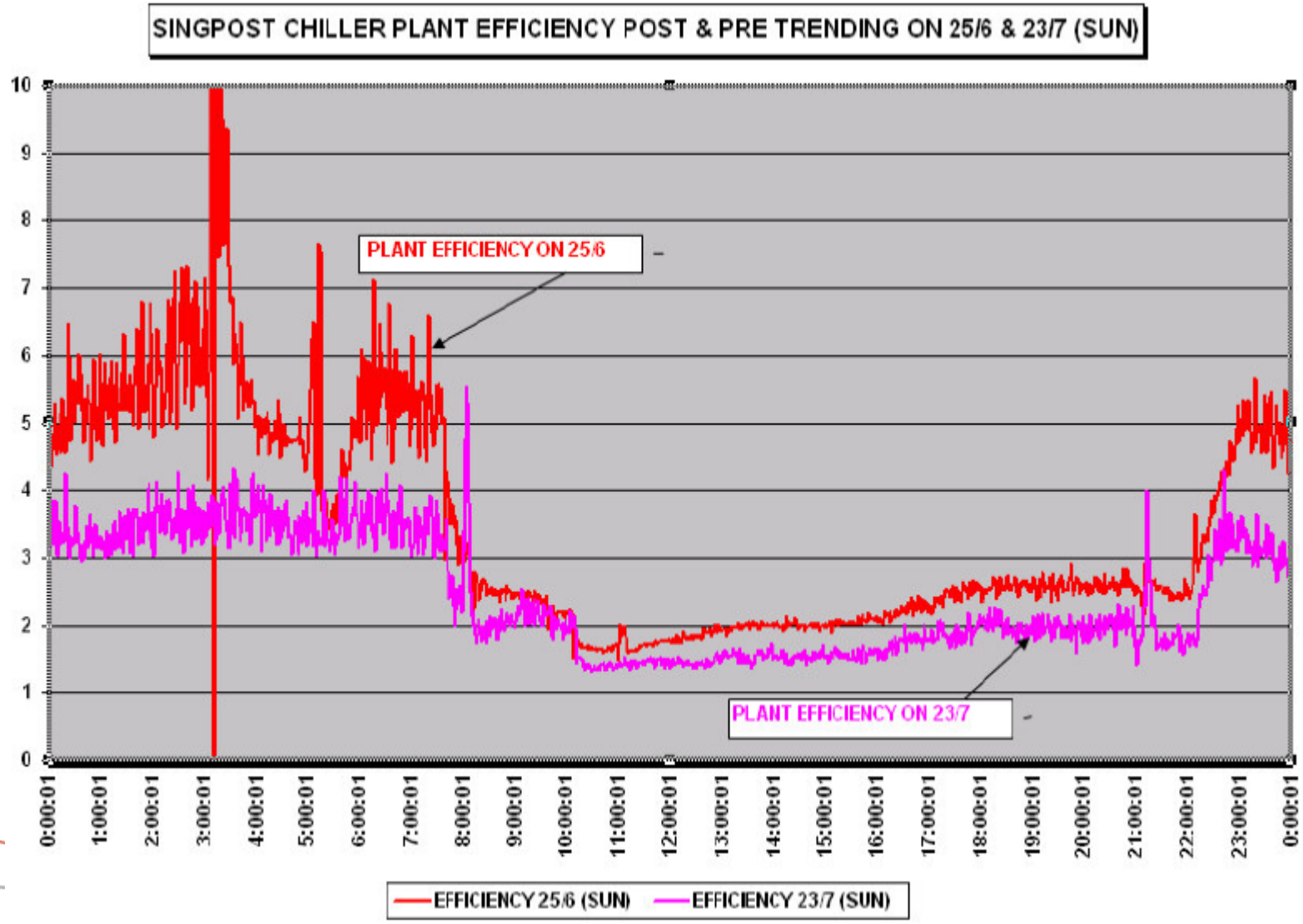


SingPost Energy Efficiency Project

Baseline Monitoring Points



Chiller System Baseline Data as provided by CPG

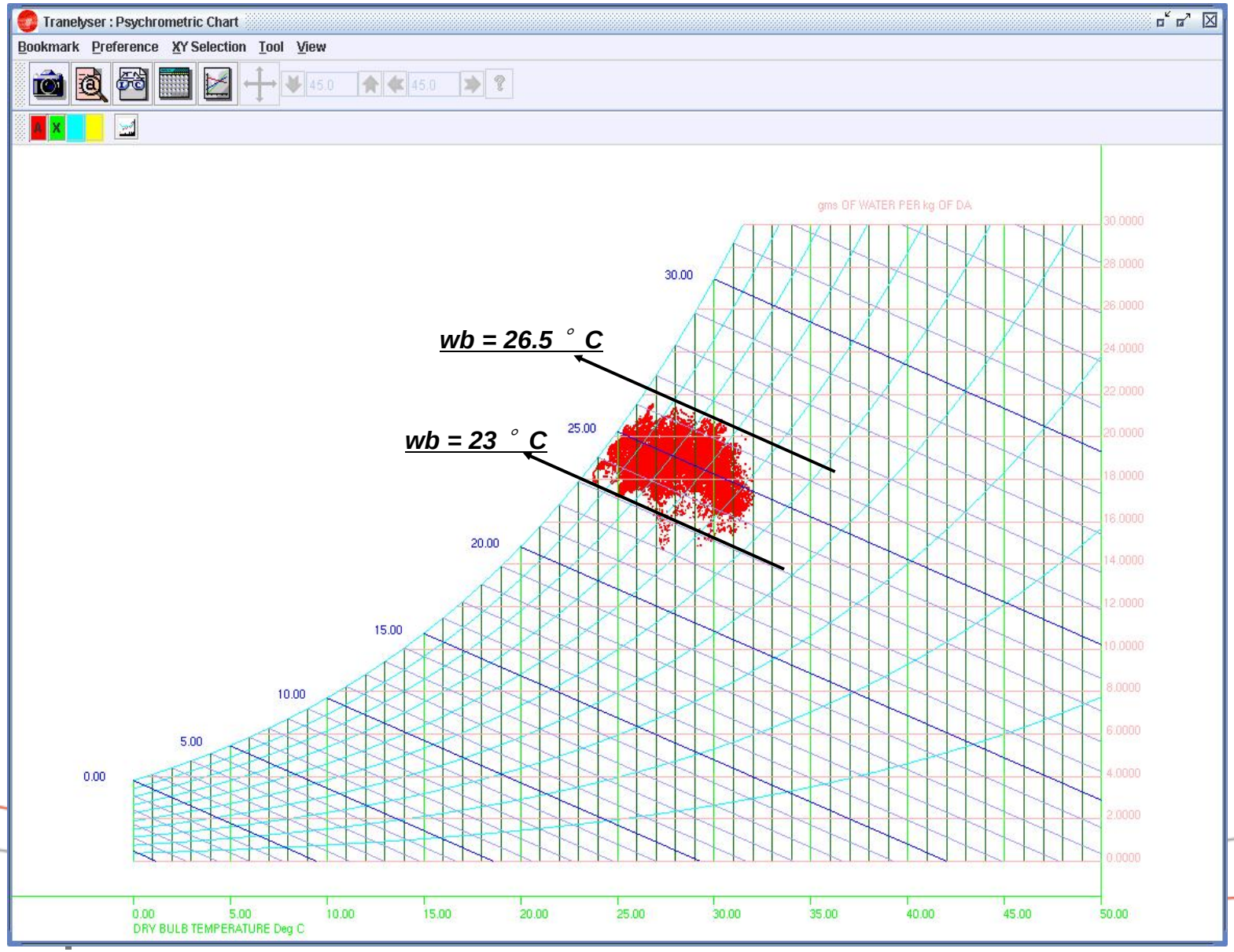


Chiller System	Weekly Consumption (kWh/week)	Plant kW/RT	Chiller kW/RT
North Spine	193,600	1.42	1.04
South Spine	110,200	0.85	0.64
NIE	152,100	1.27	0.65
N2	25,800	0.86	0.63
SCI	14,000	1.34	0.95

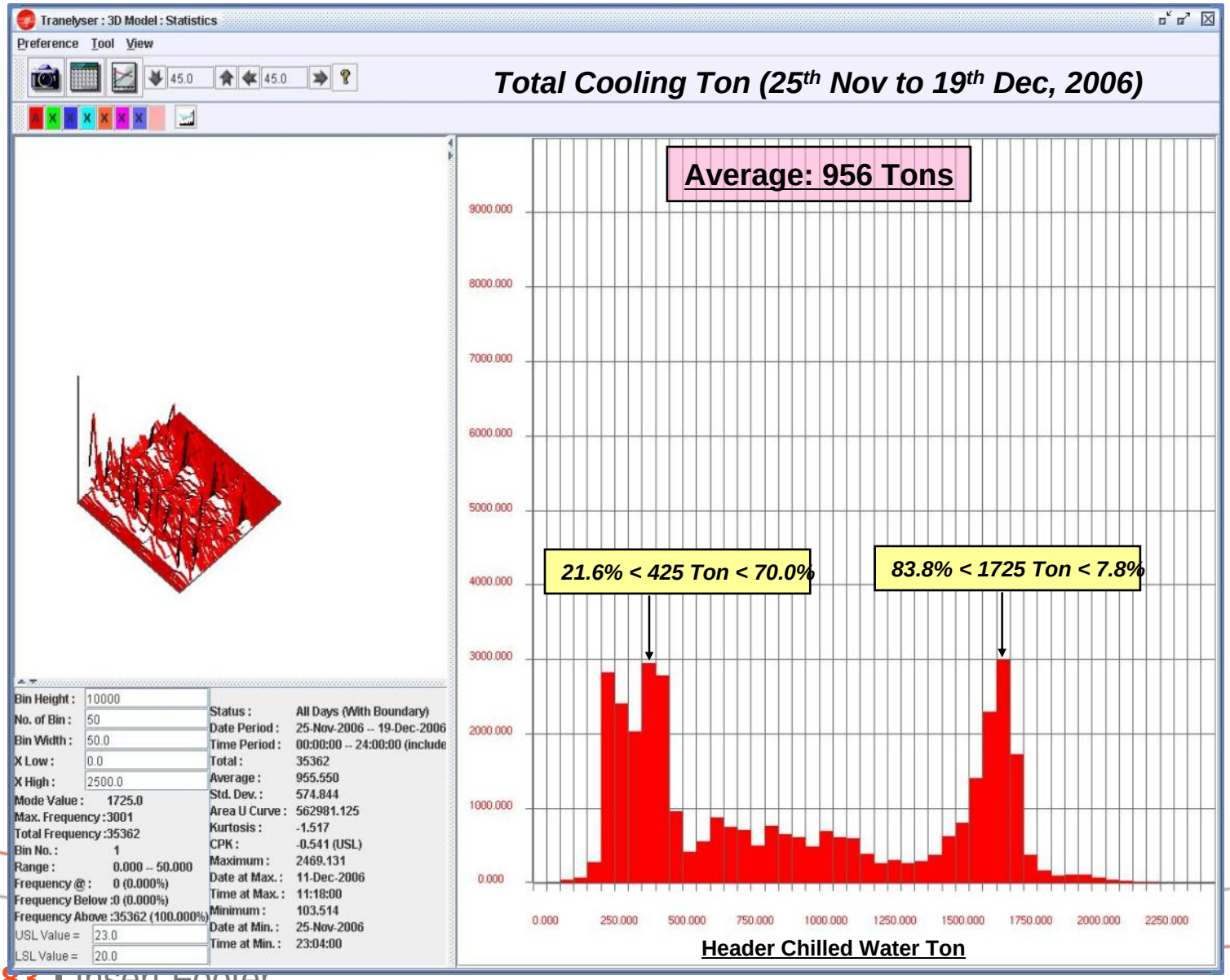
Table 1 Chiller and Chiller Plant Efficiencies

Weather Data for CT-123

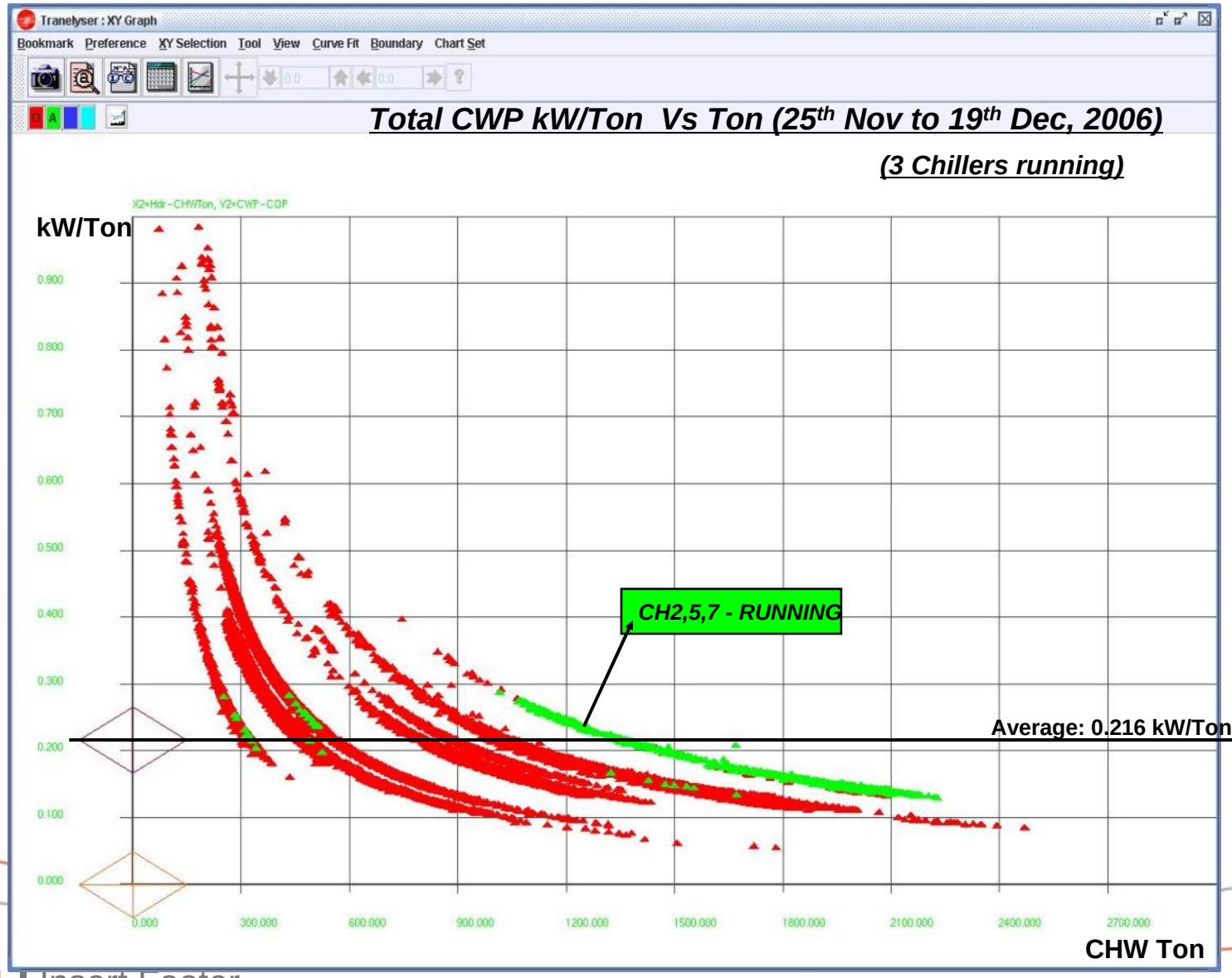
Data from 20th Nov, 2006 to 19th Dec, 2006



Component's Average



Component's Performance Chart.




EAST ENTRANCE TO B1 & B2 CAR PARKS
IN
IN
OUT
OUT

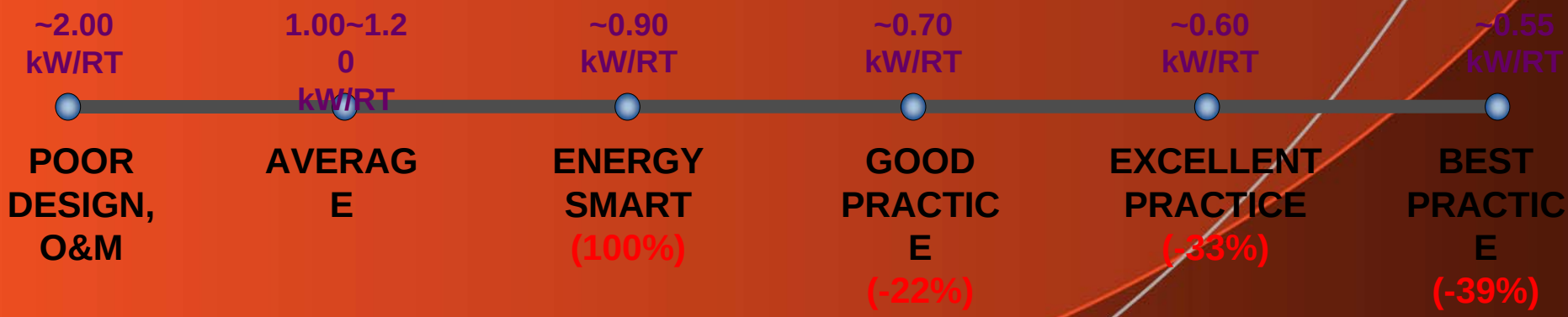

CWR
CHWR


CHWR


CAROLINA
CWP-B1

Chiller Plant System Performance (kW/RT)

PUMPS, TOWERS, CHILLERS
SINGAPORE WEATHER CONDITIONS



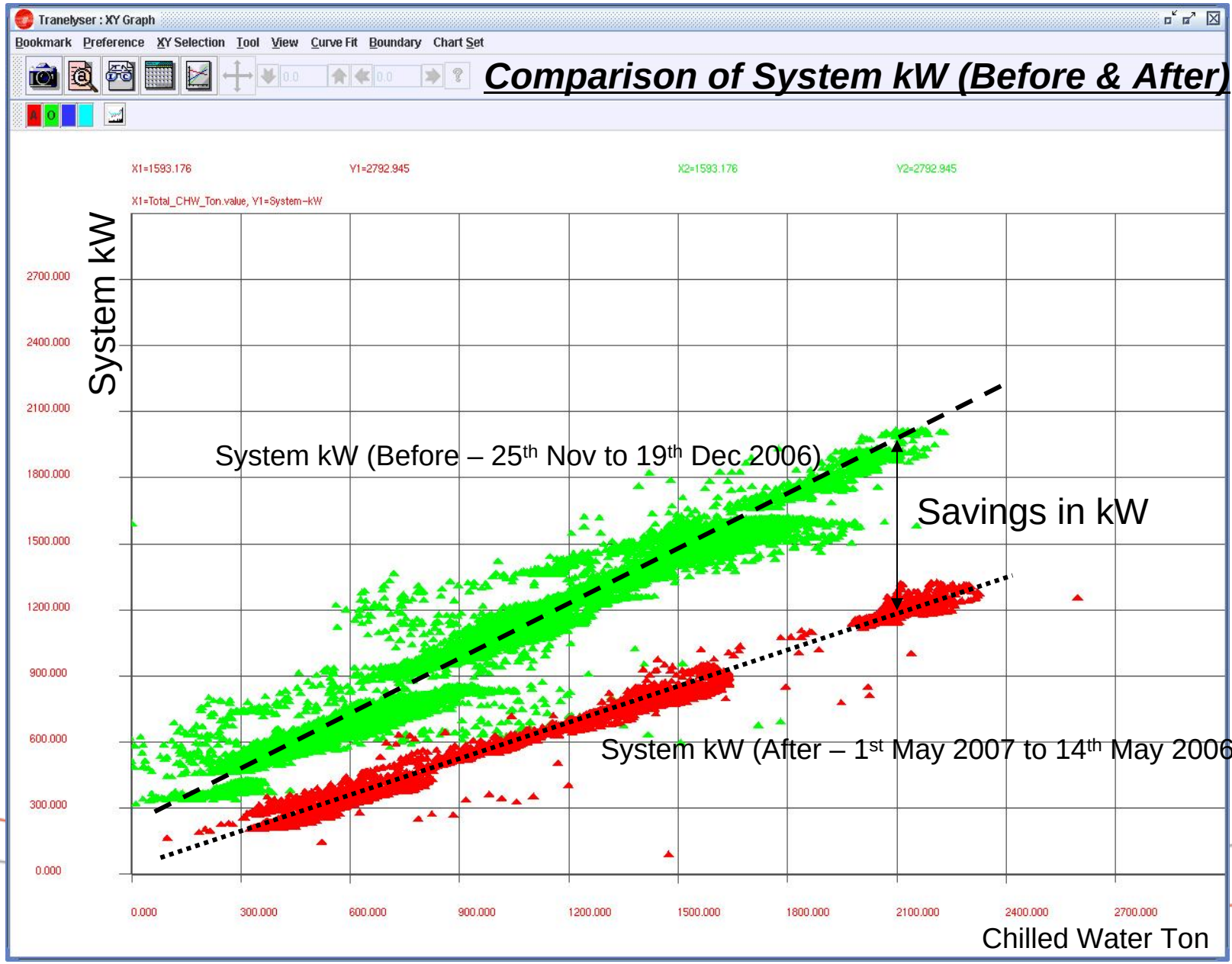
NOTES:

1. Chiller plant lifetime 15 ~ 20 years
2. Fossil fuel prices increasing
3. IPCC report says Global Warming serious problem
4. Once you commit $$$ to retrofits, you are unlikely to upgrade for many years

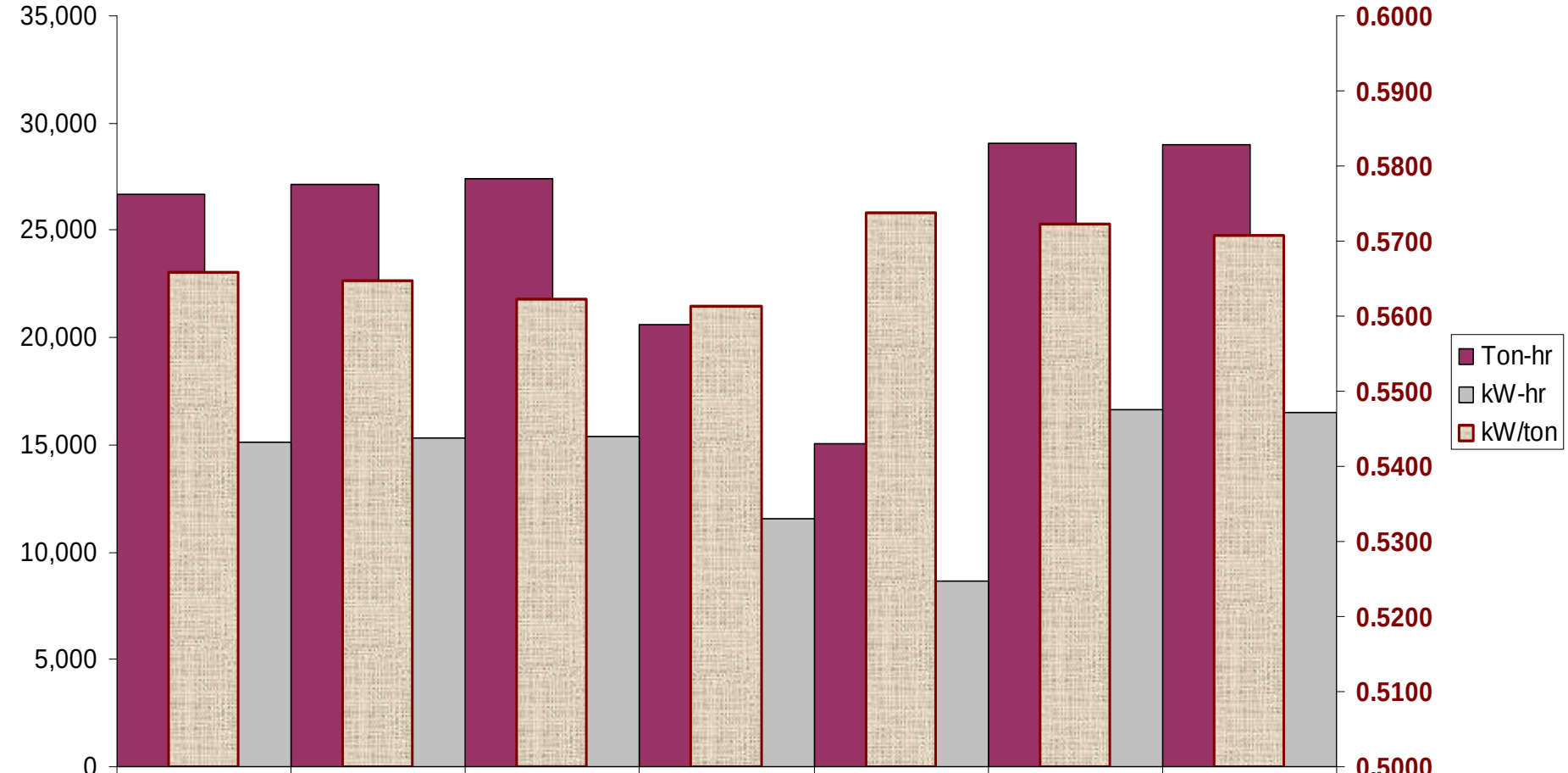
CHW Tons& Heat Balance Singapore Post Centre

CHW Ton

Heat Balance (%)

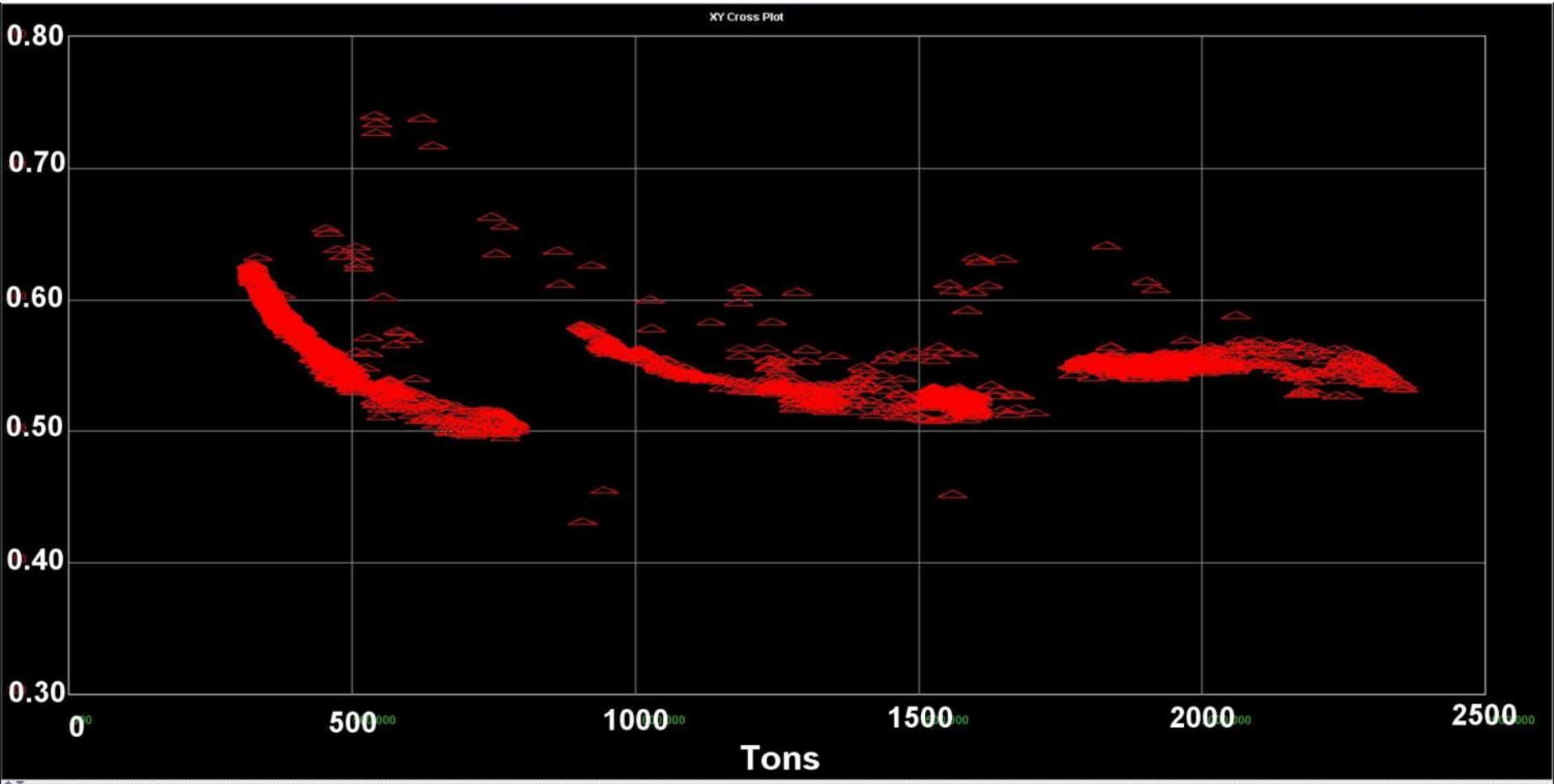

Tranelyser : XY Graph
Bookmark Preference XY Selection Tool View Curve Fit Boundary Chart Set
Comparison of System kW (Before & After)
X1=1593.176 Y1=2792.945 X2=1593.176 Y2=2792.945
X1=Total_CHW_Ton.value, Y1=System-kW
System kW
2700.000
2400.000
2100.000
1800.000
1500.000
1200.000
900.000
600.000
300.000
0.000
System kW (Before – 25th Nov to 19th Dec 2006)
Savings in kW
System kW (After – 1st May 2007 to 14th May 2006)
0.000 300.000 600.000 900.000 1200.000 1500.000 1800.000 2100.000 2400.000 2700.000
Chilled Water Ton

Singapore Post Centre – Totalized System Efficiency
1-August 2007 to 7-August-2007



	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Average
	1-Aug-07	2-Aug-07	3-Aug-07	4-Aug-07	5-Aug-07	6-Aug-07	7-Aug-07	
Ton-hr	26,671	27,128	27,394	20,627	15,051	29,077	28,975	24,989
kW-hr	15,091	15,318	15,403	11,577	8,635	16,640	16,539	14,172
kW/ton	0.5658	0.5647	0.5623	0.5612	0.5737	0.5723	0.5708	0.5673

System kW/RT SingPost 18~20 Feb 2008



Feb 2008 Clear S.M.

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	

No.	Point Name	Start Date(mm..	End Date(mm-..	High Limit	Low Limit	LSL	USL	Sampling Rate	View Rate	Folder+Point
✔	System_Eff.value	01-01-2008	02-20-2008	0.8	0.3	20.0000	23.0000	1	1	/home/SingPost/Folder2008/+Effenciency+...
	Total_CHW_Ton.value	01-01-2008	02-20-2008	2500	0	20.0000	23.0000	1	1	/home/SingPost/Folder2008/+Tonnage+9,0...

Open Bookmark | Save Bookmark | Delete Bookmark | Remove Point(s) | Save Graph | Save Data | View Graph(s)

FAR EASTERN ECONOMIC REVIEW
www.feer.com

Grand Hyatt Singapore

ASIAN INNOVATION AWARDS 2004

- BRONZE AWARD

By Barry Wain/SINGAPORE

Issue cover-dated October 21, 2004

Grand Hyatt Singapore Commissioning Data

Description	Pre-retrofit	Post-retrofit	Improvement
Chiller efficiency	0.75	0.485	35.33%
Cooling tower efficiency	0.03	0.025	16.67%
Chilled water pump efficiency	0.153	0.035	77.12%
Condenser water pump efficiency	0.116	0.035	69.83%
System efficiency	1.049	0.58	44.71%

Click me to

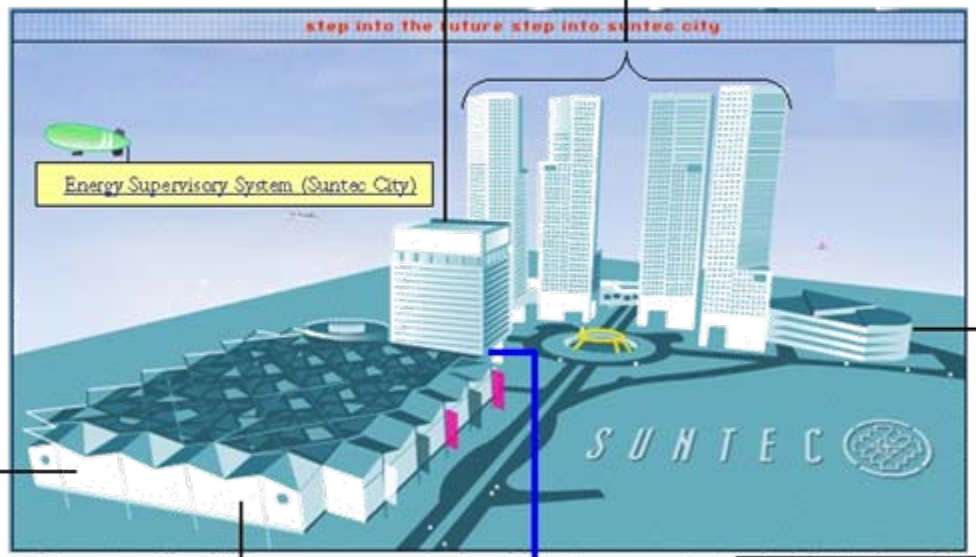
CHILLER-PLANT

Tower 5

Flow (usgpm):	1773
CHWS (°C):	6.925
CHWR (°C):	13.887
ΔT (°C):	6.962
Load (Ton):	926
DP (ft H2O):	26.456
DP (bar):	0.790

Tower 1-4

Flow (usgpm):	8258
CHWS (°C):	6.796
CHWR (°C):	13.749
ΔT (°C):	6.953
Load (Ton):	4306



Retail Mall

Flow (usgpm):	6171
CHWS (°C):	6.768
CHWR (°C):	12.358
ΔT (°C):	5.590
Load (Ton):	2587

Convention Center 1

Flow (usgpm):	2452
CHWS (°C):	6.847
CHWR (°C):	12.955
ΔT (°C):	6.108
Load (Ton):	1123

Convention Center 2

Flow (usgpm):	2523
CHWS (°C):	6.900
CHWR (°C):	10.981
ΔT (°C):	4.081
Load (Ton):	772

Flow (usgpm):	24413
CHWS (°C):	6.755
CHWR (°C):	12.930
ΔT (°C):	6.175
Load (Ton):	11306

Total Ton:	11306	
	kW	kW/Ton
Chiller:	7914	0.697
CWP:	929	0.082
PCHWP:	484	0.043
SCHWP:	282	0.025
CT:	322	0.028
System:	9932	0.875

Ansari X prize --- Space Flight

Negawatt - X Prizes

- First High Temp Chiller Plant to achieve 0.40 kW/RT
- First Low Temp Chiller Plant to achieve 0.50 kW/RT
- First low cost M&V hardware/software product for chiller plant to achieve ARI-550 accuracy or better
- First Lighting System to achieve 200 Lumens/Watt
- First HVAC system to achieve 0.65 kW/RT
- First property developer to allow real time access to various properties types for MEP systems, online documentation, etc setting high standards

IDEAS SOUGHT FOR BETTER DESALINATION – Aug 2007 Business Times, Singapore

- The Environment and Water Resources Ministry is looking for better ways to make clean water out of seawater.
- Its Environment and Water Industry Development Council is asking all local and overseas institutes of higher learning, research institutes and private sector companies to submit proposals for technologies which can desalinate seawater using a total energy consumption of not more than 1.5 kWh per m3 of water produced - less than half the energy now used by other technologies.
- The closing date is Nov 2. For more information. go to www.mewr.gov.sg/ewi .

Cheaper way found to make sea water drinkable—Straits Times, 24June2008

……Siemens Water Technologies team yesterday bagged a S$4 million grant from the Environment and Water Industry Development Council (EWI)…. used electricity instead of high pressure or heat to remove salt from sea water, and produced a cubic metre of pure drinking water on 1.5 kilowatt-hours (kWh) of power.

.

….PUB technology director Harry Seah described the novel approach as one which 'blows convention away'.

….Prof Lui …. 'This is what we call disruptive technology - and it's exactly what we're looking for.'

News of this new technology is a prelude to the cutting-edge technologies that will be on show at the Singapore International Water Week, which officially opens today.

The four-day event at the Suntec convention centre has attracted over 5,000 delegates and 390 companies in the water-technology business.

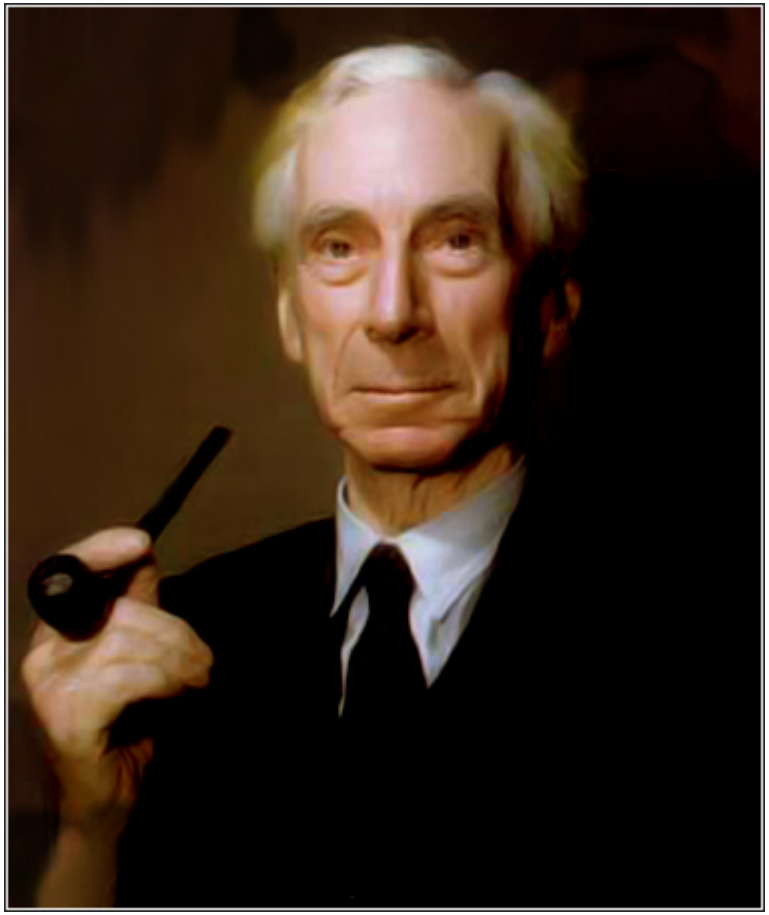
Making Energy Efficiency Accountable

Right now there is no off-the-shelf delivery process in place to develop truly effective energy efficiency improvements with long term performance assurance.

Thomas Hartman, P E
The Hartman Company

June 2007,
automatedbuildings.com

"Many people would sooner die than think. In fact they do."



- By Bertrand Russell